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ACTA RADIOLOGICA
EDITA IUSSU SOCIETATUM RADIOLOGICARUM
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VOL. 45 JANUARY 1956 FASC. 1

PERCUTANEOUS SELECTIVE ANGIOGRAPHY OF THE MAIN BRANCHES OF THE AORTA

(Preliminary Report)

by

Per Ödman

The usual method of obtaining visualization of one of the branches of the aorta is to inject contrast medium into the aorta itself near the point of origin of the vessel concerned.

The commonest type of these examinations is the so-called renal angiography, in which the aim is to render the vessels of the kidney visible by injection of contrast medium into the abdominal aorta. Similar methods have also been described for, *e. g.*, the coeliac artery with its branches (RIGLER et coll., et alios), and the arterial trunks arising from the aortic arch (HELMSWORTH et coll., et alios).

The last-mentioned group of vessels may also be examined angiographically by retrograde catheterization with contrast injection (HELMSWORTH et coll., RADNER, SELDINGER, et alios) and retrograde injection only (FREEMAN and MILLER). The subclavian artery may be examined by direct puncture of the vessel.

Contrast medium introduced into the aorta, whether the injection is performed through a catheter or a needle, is essentially distributed with the blood stream, that is, fairly arbitrarily. Hence, the possibilities of directing the solution to a certain region, so that the major portion enters one special vessel, are small. Comparatively large amounts of contrast medium in a relatively high concentration have therefore to be used in angiographic examinations of this type. This involves the risk of contrast solution in a toxic concentration entering sensitive vascular areas, particularly the brain and the kidneys. This fact has lately been brought to attention by BROMAN and OLSSON, IDBORN and BERG, ALWALL et coll., et alios.

Submitted for publication 5 September 1955.

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Angiographic examinations of the type outlined above are further unsatisfactory in that not only the aortic branch concerned but also other vessels become filled with contrast medium. A radiopaque substance in irrelevant branches of the aorta often obscures the pathologically changed structures it is desired to demonstrate. This effect is especially disturbing in lumbar aortography, in which in many cases almost all the branches arising from the abdominal aorta are filled with contrast medium.

A selective angiographic method aiming at visualization of each branch of the aorta separately, seems therefore to be desirable.

BIERMAN et coll. have tried such a procedure in a total of 24 cases. It was performed according to the following principles:

A radiopaque cardiac catheter with a fixed curve at the tip is used. The catheter is inserted into the arterial system by exposure of a suitable artery of sufficiently large size and incision of its wall through which the tip of the catheter is introduced into the lumen of the vessel. The catheter is then passed further along the arterial system under fluoroscopic control. By diverse manipulations it can then be advanced into any one of the branches of the aorta. In catheterization of the arterial branches that arise from the abdominal aorta the catheter should be inserted intra-arterially via the carotid or the brachial arteries. In order to be passed into the branches of the aortic arch it should be introduced via either femoral artery. After the tip of the catheter has been placed in the vessel concerned contrast medium in a suitable dose is injected.

The method of BIERMAN et coll. requires surgical measures under sterile precautions. This not only makes the catheterization procedure itself difficult but also seems to involve some risk. Thus, in four cases the exposed artery was occluded or otherwise not viable for various reasons (surgical errors, postoperative thrombosis, or wound infection). Such complications followed by paralysis were reported to have occurred in three cases in which the catheter was inserted via one of the carotid arteries. Hence, it can hardly be considered advisable to use these arteries in intra-arterial catheterization. Alternating with the common carotid artery, the brachial artery was used, a procedure which is probably less hazardous, although postoperative thrombosis is reported to have occurred in one case. However, it seems to be fairly difficult to guide a catheter from one of the brachial arteries, especially the right, into one of the branches of the lumbar aorta. Such a procedure is likely to be rendered still more difficult by the fact that the intra-cardiac catheters become soft and pliable at body temperature and hence do not retain a preformed curve and become less dirigible.

TILLANDER has proposed a similar technique, which also requires exposure and incision of a suitable artery for insertion of the catheter

into the arterial system. His catheter, however, is of a special design, its distal part consisting of "small steel-links connected to one another by ball and socket joints". These links can be guided by means of a strong magnetic field so that the tip of the catheter may be passed under fluoroscopic control into one of the branches of the aorta.

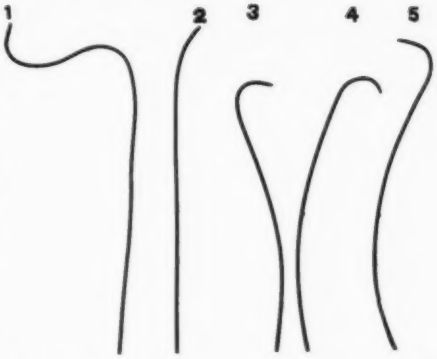


Fig. 1. Types of opaque polythene catheter for angiography of: innominate artery (Type 1), left subclavian artery (Type 2), coeliac artery (Type 3), renal artery with insertion of the catheter via the ipsolateral femoral artery (Type 4), and renal artery with insertion of the catheter via the contralateral femoral artery (Type 5).

This technique may, in practice, be regarded as a variant of the one devised by BIERMAN et coll. The possibilities of manoeuvring the catheter are probably greater with TILLANDER's than with the original method. On the other hand, the apparatus required in TILLANDER's procedure is probably complicated and difficult to handle, and consequently the catheterization itself will hardly be easier to carry out with this technique.

A percutaneous technique for selective angiography of the main branches of the aorta has been tried by the writer since the autumn of 1954. It is based on the following principles:

A radiopaque polythene catheter is used. (This was described in a paper read at the Swedish Association of Medial Radiology, 4 December, 1954, a review of which has been published in Nordisk Medicin. Further details concerning this type of catheter will be published later.) Like the polythene tubing available on the market this type of catheter may be shaped by immersion in hot water (above 72° C) so that it loses its elasticity. It is then cooled quickly so that it resumes its ordinary elastic consistence while it is fixed in the desired curved shape. In this way a polythene catheter may be moulded into any suitable shape. The type of catheter used does not become soft at body temperature but retains its preformed curve even after it has been introduced into the vascular system.

For use in selective angiographic examinations, radiopaque polythene catheters have been moulded in such a way that their shapes are suitable for the branch of the aorta it is desired to examine (see pp. 6 to 9). The ordinary distal bore of the catheter is narrower than the rest of the lumen, and close to the tip there are side holes directed away from

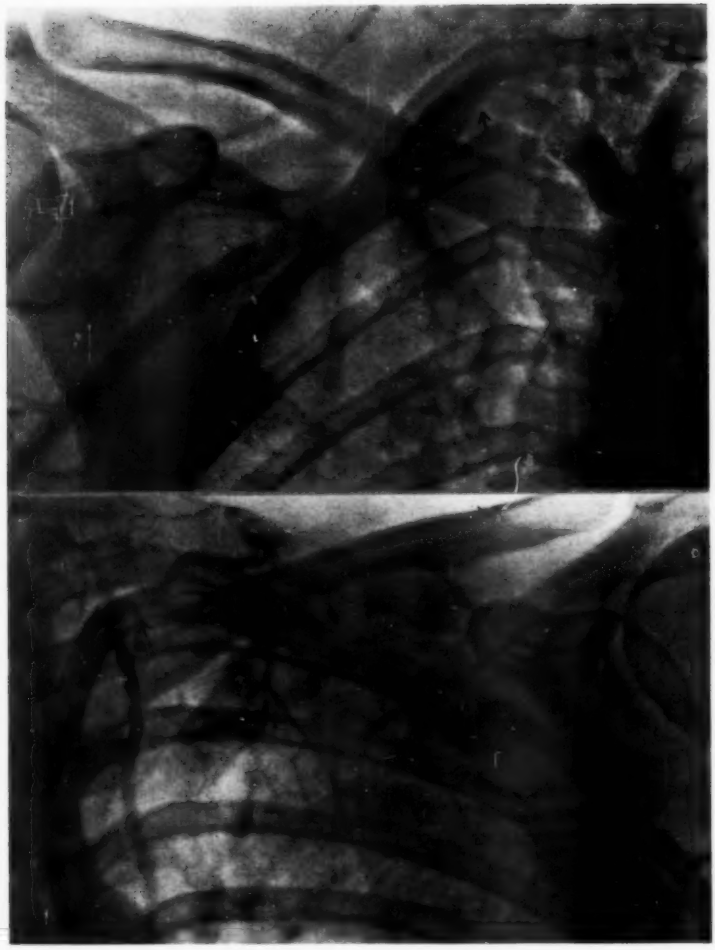


Fig. 2. Scalenus anticus syndrome with cervical ribs verified at operation. a. Catheterization of innominate artery after percutaneous introduction of catheter via left femoral artery. Visualization of innominate artery with branches after injection of 18 ml Triurol 25 %. At →, compression of right subclavian artery by right scalenus anticus muscle. b. Tip of catheter placed in left subclavian artery under fluoroscopic control; injection of 15 ml Triurol 25 %. At →, compression of left subclavian artery by left scalenus anticus muscle.

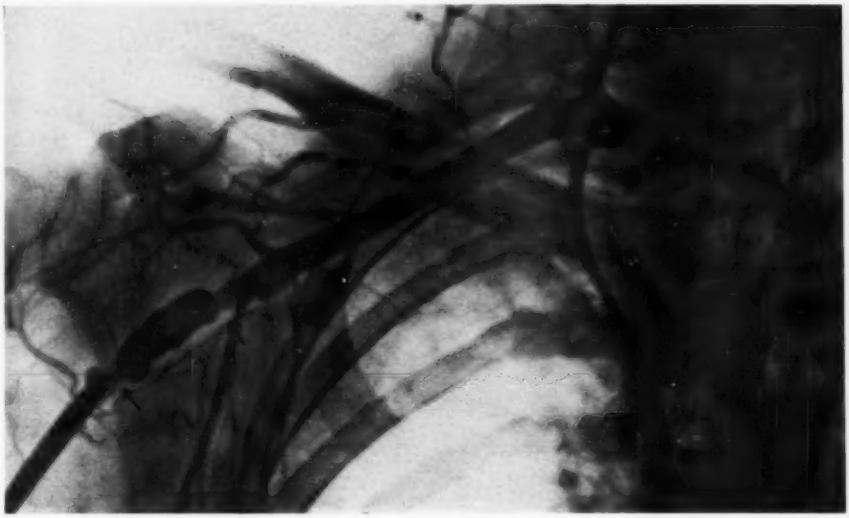


Fig. 3. Postoperative examination of traumatic aneurysm of right axillary artery (resection and transplantation of long saphenous vein). Catheter introduced percutaneously via right femoral artery; tip placed in right subclavian artery under fluoroscopic control; injection of 35 ml Rheopak 40 %. (Venous graft ↑.)

the tip. These recoil-reducing measures considerably diminish the displacement of the catheter on the injection of contrast medium (ÖDMAN).

The catheter is inserted percutaneously the femoral artery into the arterial system using SELDINGER's technique. The ordinary distal bore of the polythene tubing exactly fits SELDINGER's instrumentarium, size PE 160. The catheter is passed up the aorta until the tip lies approximately at the level of the arterial branch concerned when it may be manoeuvred in the desired direction in the aorta. It is directed so that it points towards the direction in which the artery runs from its origin. The tip is then slowly brought past the region where the artery is thought to arise. When the tip reaches the orifice of the artery it will, because of the elasticity of the catheter, make its way into the lumen of the vessel. In many instances the catheter may also be passed further out into aortic branches of the second order. The whole procedure of catheterization is carried out under fluoroscopic control. Thus, the movements of the catheter may be closely watched and it is possible to determine when the extremity is situated in the aorta or in one of its branches. After the catheter has been manoeuvred into a suitable position the contrast medium is injected, manually or by aid of a pressure ap-

Fig. 4. Catheter introduced percutaneously via left femoral artery; tip manoeuvred up the right common carotid artery under fluoroscopic control.

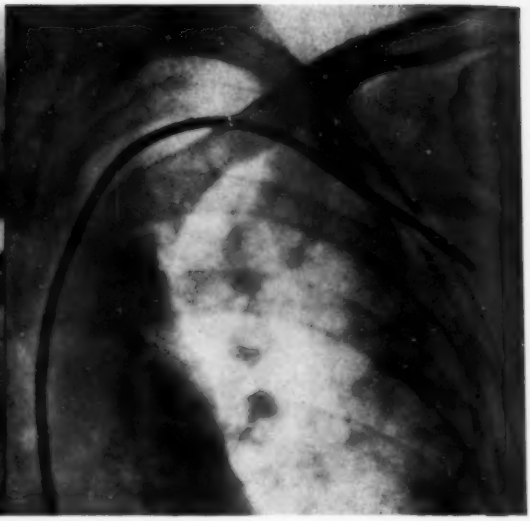


Fig. 5. Catheter introduced percutaneously via left femoral artery; tip of catheter guided into left brachial artery under fluoroscopic control.

paratus. The dose and concentration of the medium may be adjusted so that only the vascular area concerned is clearly visualized.

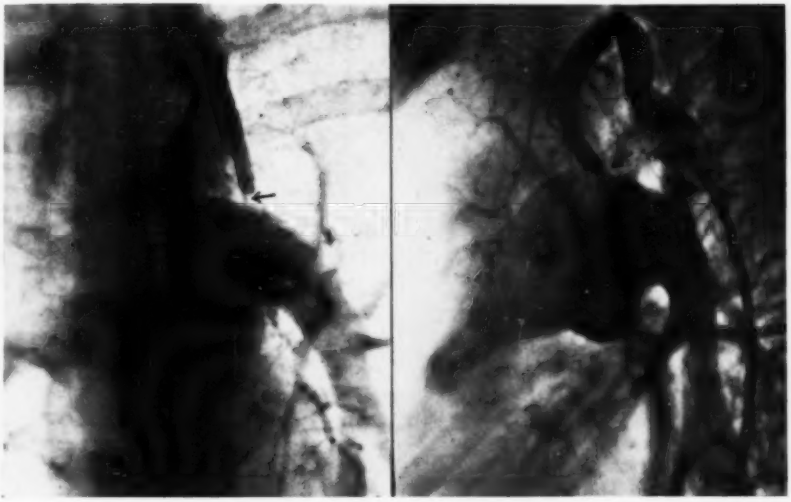
Up to the present some 20 angiographic examinations by this selective technique have been carried out. Experiences have shown that each arterial branch requires its special shaped catheter and modification of the technique. The different arterial branches have been examined as follows.

1. Angiographic examinations of the innominate artery:

The catheter near its extremity is modelled as an S (Fig. 1, Type 1). It is placed so that the tip points forwards and upwards in the upper part of the ascending aorta. The catheter is then slowly retracted under control to ensure that the initial direction of the tip is maintained. At the point of origin of the innominate artery the tip will make its way into the lumen of the artery. The contrast medium may at this stage be injected if so desired in the particular case (Fig. 2 a). If not, the catheter may be advanced further into the branches of the innominate artery (Figs. 3 and 4), so that contrast medium may be introduced only into the right subclavian artery, or into the right common carotid artery alone.

2. Angiographic examinations of the left subclavian artery:

For this purpose a catheter that is slightly bent distally is used (Fig. 1, Type 2). After it has been passed into the upper part of the descending aorta the tip may be



a b

Fig. 6. Postoperative examination of Fallot's tetrad (anastomosis according to Blalock between left subclavian artery and pulmonary artery); tip of catheter lies in left subclavian artery; injection of 35 ml Rheopak 40 %. Visualization of left subclavian artery, pulmonary artery, and junction between these vessels, which is very narrow (→). Collateral circulation between systemic arteries and pulmonary circulation in upper part of anterior mediastinum outlined. a. A.p. b. Lateral.

manoeuvred into the left subclavian artery by pushing the catheter cranially (Figs. 2 b and 6). It may also be brought further out into the arterial trunks of the arm (Fig. 5). The contrast medium is injected into a suitable region according to the requirements of the particular case (Figs. 2 b and 6).

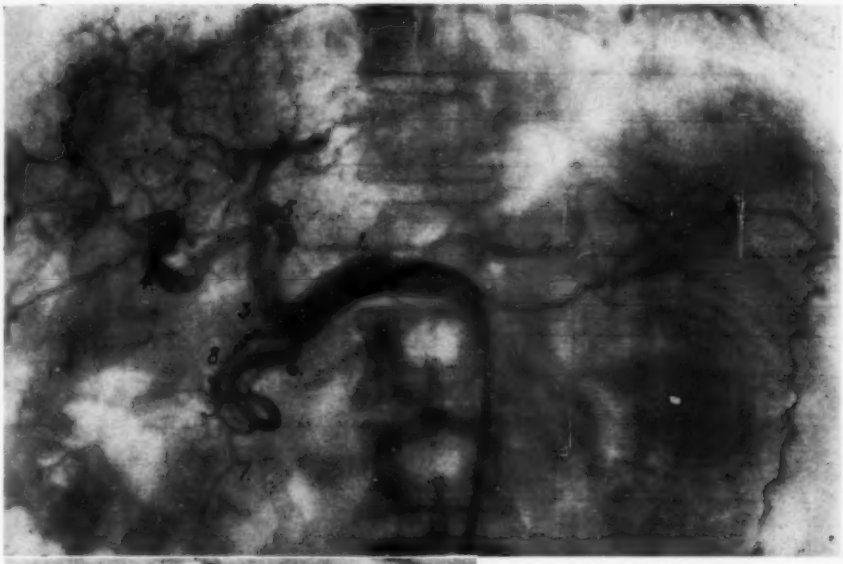
3. Angiographic examinations of the coeliac artery:

Catheterization of this artery requires a catheter the whole length of which is bent in an S-shape with a distinct accentuation close to the extremity (Fig. 1, Type 3). The patient is examined in the supine position, the lumbar curvature of the spine being straightened out as far as possible. This facilitates the manoeuvring of the catheter in the abdominal aorta. Screening is carried out mainly in the lateral view. The catheter is passed up the abdominal aorta to the level of the diaphragm. In this position it is placed so that its tip points in a ventral direction. The catheter is then gently pulled caudally under close control to ascertain that the extremity retains its initial direction. When it reaches the point of origin of the coeliac artery it slips into the lumen of this vessel (Fig. 7 a). This may generally be readily seen on screening. Occasionally, however, it is difficult to localize the tip of the catheter in relation to the various vessels. This is especially the case when the coeliac artery deviates laterally towards either side (Figs. 8 and 9). Under such circumstances the position may be judged by test exposures during the injection of relatively small amounts of contrast solution (20 ml of Umbradil 35 %; Fig. 8). After it has been ascertained that the tip of the catheter lies in the coeliac artery, angiographic examination is carried out by injection of 30 to

a b

Fig. 7. Hodgkin's disease. a. Lateral. Catheter inserted percutaneously via right femoral artery. Distal part of catheter, introduced into coeliac artery, points ventrally. b. A.p. Enlargement of spleen. 35 ml Umbradil 50 % injected. Venous phase exposed about 10 seconds after injection started. Splenic vein and portal vein with their branches clearly visualized. Concentration of contrast medium in parenchyma of spleen and liver.

Fig. 8. A. p. Coeliac artery deviates to the left. Injection of 20 ml Umbradil 35 %. Early arterial phase. 1. Coeliac artery. 2. Splenic artery. 3. Left gastric artery. 4. Common hepatic artery. 5. Gastro-duodenal artery. 6. Main hepatic artery.



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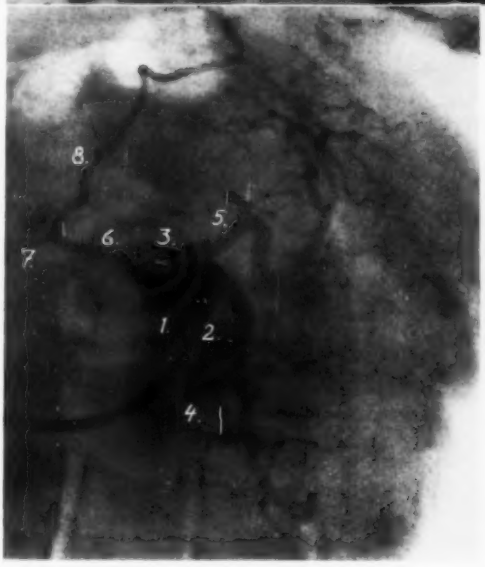


b

Fig. 9. Splenectomy. Catheter introduced percutaneously into arterial system via right femoral artery; tip guided into coeliac artery under fluoroscopic control. (The vessel deviates to the right.) Injection of 35 ml Umbradil 50 %.

Visualization of coeliac artery and branches. 1. Common hepatic artery (dilated). 2. Left gastric artery. 3. Main hepatic artery. 4. Right hepatic artery. 5. Left hepatic artery. 6. Gastro-duodenal artery. 7. Superior pancreatico-duodenal artery. 8. Right gastro-epiploic artery.

a. Frontal. (Note concentration of contrast medium in liver parenchyma.) b. Lateral.

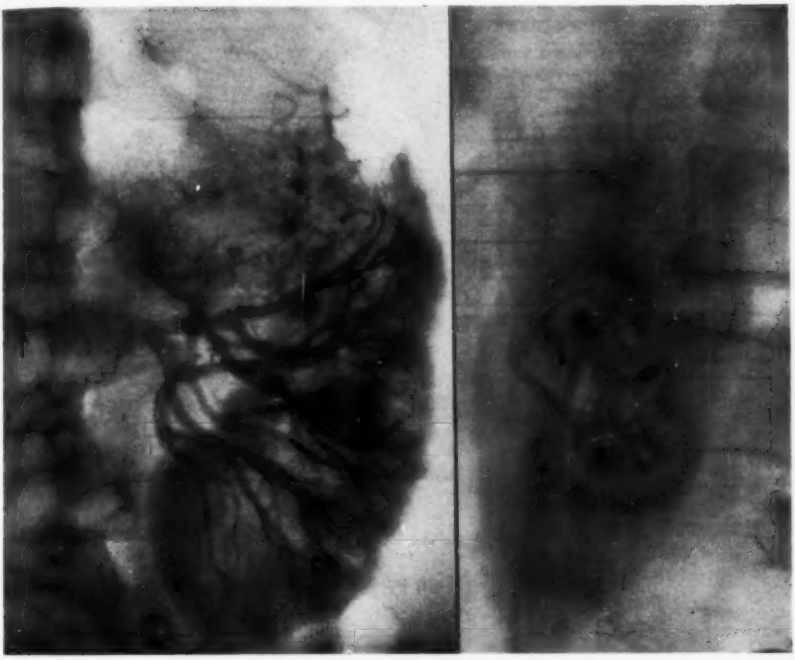
a b

Fig. 10. a. Catheter introduced percutaneously into arterial system, via left femoral artery; tip guided into *ipsolateral* renal artery under fluoroscopic control. b. Percutaneous insertion of catheter via right femoral artery. Catheterization of *contralateral* renal artery. Compare shape of catheter in a and b.

50 ml of Umbradil 50 % at a rate of 10 to 12 ml of solution per second. Exposures may be made in two planes at right angles (Fig. 9), which also facilitates the identification of various contrast-filled vessels and the interpretation of pathologically changed structures. In this type of examination visualization is obtained not only of the branches of the coeliac artery but also of the venous return-flow, especially in the splenic and the portal vein (Fig. 7 b). More or less distinct concentration of contrast medium in the tributary parenchymatous organs may also be obtained (Figs. 7 b and 9). The series of exposures in these examinations should therefore comprise a minimum of 30 seconds, so that there will be time for different phases of the contrast circulation to be recorded.

4. Angiographic examinations of the renal arteries (selective renal angiography):

For catheterization of the renal arteries the whole length of the catheter should be slightly curved with a distinct accentuation close to the extremity (Fig. 1, Type 4). With this type of catheter the renal artery to be catheterized is best reached via the femoral artery on the *same* side. This procedure is the most suitable for contrast visualization of the vessels of the kidney. If this method of catheterization cannot be carried out, the femoral artery on the other side has to be used. In that case the whole length of the catheter should be modelled to an S-shape with an extra-marked curve close to the



a b

Fig. 11. Hypernephroma of left kidney. (Same case as Fig. 10 b.) Percutaneous left-sided selective renal angiography, 15 ml Triurol 25 % injected. Arterial phase. Pathologic vascular structures in upper half of kidney, characteristic of hypernephroma. a. True a. p. of kidney. (Tip of catheter ↑). b. True lateral.

extremity (Fig. 1, Type 5). In catheterization of the renal arteries the catheter is placed in the aorta above or below the region where the renal artery is believed to branch off, the tip of the catheter pointing towards the side concerned. The catheter is then passed gently caudally or cranially, as desired, under control to ensure that the tip retains its initial direction. At the point of origin of the renal artery the tip will make its way into the lumen of the vessel, which may be noted fluoroscopically without difficulty (Fig. 10 a and b). The contrast medium, up to a maximum dose of 15 ml of Umbradil 35 % or Triurol 25 % is injected manually or by aid of a pressure apparatus, at a rate of 8 to 10 ml per second. The injection of the solution should be performed with the tip of the catheter reaching only a short distance inside the renal artery in order that all its branches be visualized and the contrast medium distributed over the whole vascular bed of the kidney. If the tip of the catheter lies too near the periphery the result may be that only one or a few of the arterial branches will be visualized, with an unnecessary high concentration of contrast medium in the corresponding vascular area. In the presence of anomalies of the renal arteries (aberrant renal arteries) it is best to try to catheterize each vessel separately.

Selective renal angiography has been performed in two planes at right angles. The

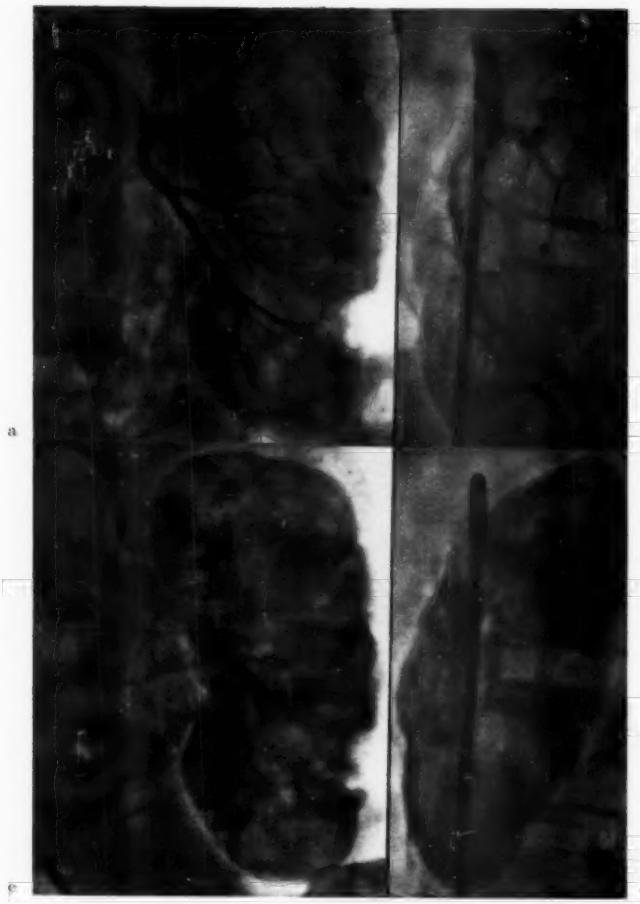


Fig. 12. Chronic pyelonephritis. Percutaneous left-sided selective renal angiography, 15 ml Triurol 25 % injected. a. Arterial phase. (True a. p. of kidney.) b. Arterial phase. (True lateral.) c. Venous phase with concentration of contrast medium in parenchyma. (True a.p. of kidney.) d. Venous phase with concentration of contrast medium in parenchyma. (True lateral.)

patient should be placed so that the kidney is exposed in its true antero-posterior and lateral projection, respectively (Figs. 11 and 12). The different phases of the passage of the contrast medium through the renal vascular bed should be followed (Fig. 12).

The selective angiographic examinations described have been carried out without complications and have throughout been strikingly easy to perform. To some extent, the technique can probably be rendered

more selective. There are, for instance, obvious possibilities of examining certain branches of the subclavian artery individually by the angiographic technique. Contrast filling of the branches of the coeliac artery one by one, could probably also be obtained.

Apart from the above-mentioned branches of the aorta, other branches have also been catheterized, although without an attendant angiographic examination; these include the superior mesenteric artery. Furthermore, when the catheter is inserted via the femoral artery on one side it may be passed through the bifurcation of the abdominal aorta into the common iliac artery on the other side.

Conclusions

It is felt that the chief advantages of the technique described are as follows:

A radiopaque catheter may be introduced percutaneously into the arterial system, manoeuvred under fluoroscopic control, and advanced into the major branches of the aorta.

The contrast medium may be injected in an adequate dose and concentration, and consequently adjusted to the special conditions of the examination.

Visualization of irrelevant vascular areas, which is undesirable, is avoided.

The risk of deleterious effects due to the toxicity of the contrast medium is greatly reduced in comparison to earlier current methods. This is of particular importance in contrast filling of the renal vessels. In ordinary renal angiography, both kidneys have to be subjected to a more or less arbitrary dose of contrast medium. In selective renal angiography the medium is introduced into one kidney only, and the dosage can also be regulated with respect to such factors, on the one hand, as the degree of opacity required and, on the other, the risk of injury to the renal parenchyma.

SUMMARY

A preliminary report is given of percutaneous selective angiography of the main branches of the aorta. A new type of radiopaque polythene catheter is introduced percutaneously. Moulded in such a way that its shape is adjusted to the aortic branch to be examined, the tip of the catheter is advanced under fluoroscopic control into one of the branches of the aorta, where the contrast medium is injected.

ZUSAMMENFASSUNG

Ein vorläufiger Bericht über die perkutane selektive Angiographie der Hauptzweige der Aorta wird abgegeben. Ein neuer Typus eines röntgendichten Polythenkatheters

wird perkutan eingeführt. Die Spitze des Katheters, die so geformt ist, dass ihr Aussehen der zu untersuchenden Aortaabzweigung angepasst ist, wird unter Durchleuchtungskontrolle in einen der Äste der Aorta eingeführt; hier wird das Kontrastmittel injiziert.

RÉSUMÉ

L'auteur présente une note préliminaire sur l'angiographie sélective percutanée des principales branches de l'aorte. Un cathéter radio-opaque en polyéthylène d'un nouveau type est introduit par voie percutanée. Modelée de façon que sa forme s'adapte à la branche aortique à examiner, l'extrémité du cathéter est poussée sous contrôle radioscopique dans une des branches de l'aorte, où l'on injecte le produit de contraste.

REFERENCES

Alwall, N., Johnsson, S., Tornberg, A. & Werkö, L.: Acute renal failure following angiography. Acta chir. Scandinav. 109 (1955), 11.

Bierman, H. R., Miller, E. R., Byron, R. L., Dod, K. S., Kelly, K. H. & Black, D. H.: Intra-arterial catheterization of viscera in man. Am. J. Roentgenol. 66 (1951), 555.

Broman, T. & Olsson, O.: The tolerance of cerebral blood-vessels to a contrast medium of the diodrast group. Acta radiol. 30 (1948), 326.

Freeman, N. E. & Miller, E. R.: Retrograde arteriography in diagnosis of cardiovascular lesions. I. Visualization of aneurysms and peripheral arteries. Ann. Int. Med. 30 (1949), 330.

Helmsworth, J. A., McGuire, J. & Felson, B.: Arteriography of the aorta and its branches by means of the polyethylene catheter. Am. J. Roentgenol. 64 (1950), 196.

Idborn, H. & Berg, N.: On the tolerance of the rabbit's kidney to contrast media in renal angiography. Acta radiol. 42 (1954), 121.

Ödman, P.: Ny kateter för kontrastundersökning av hjärtat och de stora kärlen. (Swedish.) Nord. Med. 54 (1955), 1577.

— Thoracic aortography by means of a radiopaque polythene catheter inserted percutaneously. Acta radiol. (in press).

Radner, S.: Subclavian angiography by arterial catheterization. Acta radiol. 32 (1949), 359.

Rigler, L. G. & Olfelt, P. C.: Abdominal aortography for roentgen demonstration of the liver and spleen. Am. J. Roentgenol. 72 (1954), 586.

Seldinger, S. I.: Catheter replacement of the needle in percutaneous arteriography. Acta radiol. 39 (1953), 369.

— Localization of parathyroid adenomata by arteriography. Acta radiol. 42 (1954), 353.

Tillander, H.: Magnetic guidance of a catheter with articulated steel tip. Acta radiol. 35 (1951), 62.

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PERCUTANEOUS CATHETERIZATION OF THE RENAL ARTERY

by

Paul Edholm and *Sven Ivar Seldinger*

There are good reasons why catheterization of the renal arteries can be interesting. From the roentgenologic point of view, there are not infrequent reports of damage to the kidneys by aortography. By injection directly into the renal artery an amount of contrast medium adequate for the examination of the kidney in question may be chosen. The difficulty in controlling the distribution of the medium by aortic injection is eliminated and the contralateral kidney preserved from any supply of contrast medium administered intra-arterially. This may be especially valuable in the numerous cases where the kidney examined is likely to be removed.

BIERMAN et coll. have reported on catheterization of visceral arteries in man using rubber tubing introduced via various exposed arteries. RAPPAPORT has performed experiments in dogs with guided catheterization of abdominal vessels from the exposed femoral artery. He used a steerable metal leader as a guiding instrument. In Sweden, TILLANDER has reported on arterial catheterization in dogs with the help of magnetic guidance and has also used this method in human subjects. GIDLUND has used guided catheters, chiefly intravenously but also intra-arterially. For controlling the curvature he has applied various methods, one of which resembles ours. ÖDMAN has also worked simultaneously and independently of us with a similar technique.

We decided on the following requirements for a practical technique: it should be performed percutaneously, the convenient femoral artery should be used, and the equipment should be simple and easily available.

The equipment is the same as the one described by SELDINGER in a previous paper: 1) A puncture needle. 2) A flexible metal guide. 3) A

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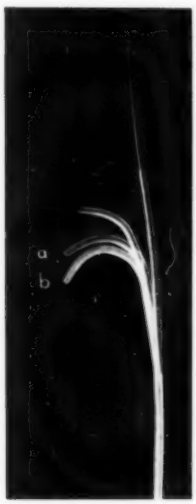

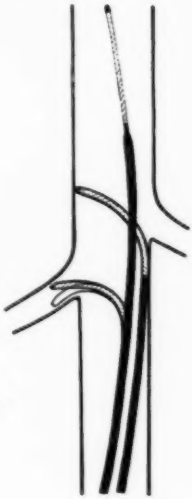

Fig. 1 Fig. 2 Fig. 3

Fig. 1. Multiple exposures showing the movement of the catheter during the withdrawal of the guide. a) The guide withdrawn to the tip of the catheter. b) The guide totally withdrawn.

Fig. 2. The catheter pushed up above the renal artery from the puncture site in the inguinal region. The small curvature at the tip tends to turn in the same direction as the long curvature of the entire catheter.

Fig. 3. Steps in introducing the catheter into the renal artery. Compare Fig. 1.

polyethylene catheter of the same gauge as the needle or somewhat larger. The catheter should be bent to a form illustrated in Fig. 1 b with the perpendicular distance from the tip to the straight part somewhat longer than the diameter of the aorta. This is easily done by warming the catheter cautiously above a match flame. The distal 3 cm of the guide are more flexible than the rest. Consequently, when the guide is introduced into the lumen of the catheter and extended 3 cm beyond its tip, the curvature of the catheter is straightened out. When the guide is withdrawn the catheter will again bend (Fig. 1). The flexible tip of the guide may remain in the curvature of the catheter to serve as a radio-opaque indicator.

The technique for introduction of the catheter into the aorta is the same as described in the paper mentioned above, *i. e.* after puncture, the needle is replaced by the catheter with the help of the guide. The guide and catheter, with the curvature straightened out, are pushed up into the aorta to the level of the renal artery. The extremity of the guide

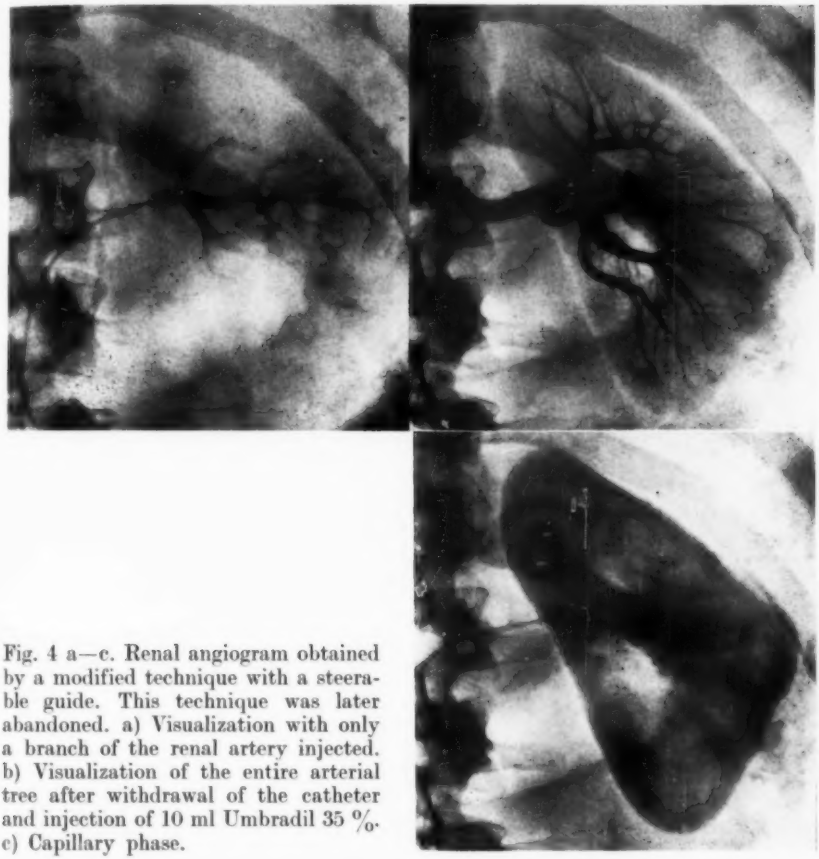

Fig. 4 a—c. Renal angiogram obtained by a modified technique with a steerable guide. This technique was later abandoned. a) Visualization with only a branch of the renal artery injected. b) Visualization of the entire arterial tree after withdrawal of the catheter and injection of 10 ml Umbradil 35 %. c) Capillary phase.

is withdrawn to the tip of the catheter, causing the latter to become curved (Fig. 2). Under fluoroscopy the catheter is placed with its tip towards the desired kidney and is moved along the aortic wall. When it reaches the renal artery the tip of the catheter moves outside the lateral border of the aorta. This movement was strikingly apparent in most of our cases (Fig. 3).

It has proved best to catheterize from the femoral artery on the same side as the kidney in question, because the tip of the catheter tends to turn in the same direction as the long curvature of the entire catheter (Fig. 2). An image amplifyer has not been found essential but has proved to be of great help. This permits the work to be carried out in an ordinarily illuminated room and makes it possible to control the catheter

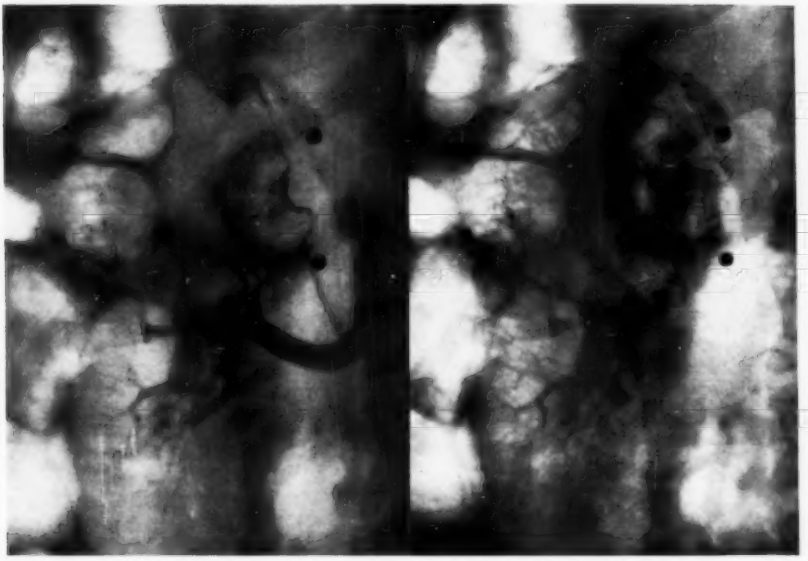

Fig. 5. Hypernephroma. Seven (7) ml Umbradil 50 %. Some of the contrast medium injected intra-aortically due to the recoil of the catheter. Note the very early branching off of an upper polar artery which supplies the tumor to a significant degree.

into the correct position in the renal artery, where a rapid injection of only 1 to 2 ml of Umbradil 35 % suffices for fluoroscopic identification. Another possibility for control is the absence of any local sensations when the injection is made exclusively into the renal artery whereas there is a feeling of burning in the pelvis or legs when even small amounts are injected intra-aortically.

When the catheter is correctly placed, the patient should, by means of a suitable arrangement, be moved from the fluoroscopy table to the film changer in an unaltered position.

This technique failed in one case in which a sinuous aorta and iliac artery made control of the movements of the catheter difficult. It succeeded in 8 other cases and was only difficult in one of these. In the latter it was necessary to exactly localize the renal artery by help of a minute amount of contrast medium injected along the aortic wall.

The renal arteriograms were performed with doses of contrast medium varying from 4 ml and 1 ml Umbradil 35 % and 70 %, respectively, up to 10 ml and 7 ml Umbradil 35 % and 50 %, respectively, manually injected. No complications were observed. If the catheter was bent as

in Fig. 1 b, it remained near the wide entrance to the renal artery, which offered certain advantages over its deeper passage into the vessel. There was better space for free blood flow around it and spastic contraction of the artery was probably easier to avoid. In any case, none was observed in our patients. The risk of injecting only a branch of the artery (as in Fig. 4) was smaller. Early branching is not uncommon; polar arteries, arising from different parts of the renal arteries, occur in 22 % of kidneys (HELLSTRÖM). (See Fig. 5.)

Fig. 6. Arterial phase of renal angiogram in a kidney with an aberrant artery. Four (4) ml Umbradil 50 %. No artery supplying the lower pole visualized. Slight arterial displacement laterally in the middle part of the kidney caused by a cyst, which was verified by puncture.

However, the occurrence of aberrant arteries directly originating from the aorta (Fig. 6) diminishes the value of selective renal angiography. In a material consisting of 1,727 kidneys collected from several series including his own, HELLSTRÖM found such vessels in 22.9 %. In this minor group there is a risk that a pathologic process may be situated in the area supplied by an artery not visualized. Such an area may perhaps also be misinterpreted as, for instance, an avascular tumor.

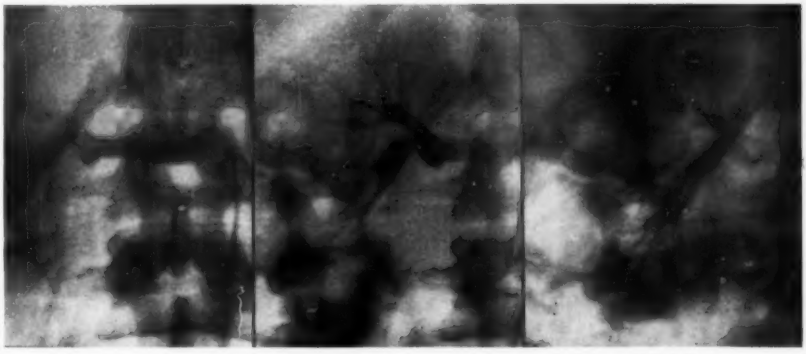

Fig. 7. Normal renal angiogram after very rapid injection of 1 ml Umbradil 70 %. As in all cases, one additional ml remained in the catheter. 0.15 sec between the exposures.

Because of the continued discussion regarding the hazards of aortography it is too early to judge the roentgenologic value of the method reported. It may, anyhow, be adequate in selected cases where special care of the kidneys is necessary.

SUMMARY

The authors describe a simple equipment and technique for percutaneous catheterization of the renal artery via the femoral artery with a polyethylene catheter. Some of the advantages and disadvantages of selective renal angiography are discussed.

ZUSAMMENFASSUNG

Die Verfasser beschreiben eine einfache Ausrüstung und Technik für die perkutane Katheterisierung der Nierenarterie via die femorale Arterie mit einem Polyethylenkatheter. Einige der Vor- und Nachteile der selektiven renalen Angiographie werden besprochen.

RÉSUMÉ

Les auteurs décrivent une instrumentation simple et la technique de cathétérisme percutané de l'artère rénale par l'artère fémorale avec un cathéter en polyéthylène. Ils discutent certains des avantages et des inconvénients de l'angiographie rénale sélective.

LITERATURE

Bierman, H. R., Miller, E. R., Byron Jr. R. L., Dod, K. S., Kelly, K. H., and Black, D. H.: Intra-arterial catheterization of viscera in man. Am. J. Roentgenol. 66 (1951), 555.

Gidlund, Å.: Personal communication.

Hellström, J.: Über die Varianten der Nierengefässe. Zschr. f. urol. Chir. 24 (1928), 253.

Ödman, P.: Personal communication.

Rappaport, A. M.: The guided catheterization and radiography of abdominal vessels. Canad. M. A. J. 67 (1952), 93.

Seldinger, S. I.: Catheter replacement of the needle in percutaneous arteriography. Acta radiol. 39 (1953), 368.

Tillander, H.: Magnetic guidance of a catheter with articulated steel tip. Acta radiol. 35 (1951), 62.

— Personal communication.

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SELECTIVE ANGIOGRAPHY OF THE ABDOMINAL AORTA WITH A GUIDED CATHETER

by

Hans Tillander

During recent years angiography has come into widespread use and a great deal of experience with the various forms of this technique has been accumulated. The risk of complications and the need for refined diagnosis have forced us to evolve increasingly exact methods. In the original technique (Dos Santos 1937) contrast medium was injected into the entire abdominal aorta with its branches, in other words, also into areas which were of no interest to the particular examination. Despite the fact that relatively atoxic contrast media have been developed, the high concentrations used represent a risk of serious damage to sensitive organs (Broman & Olsson 1949, Idbohrn & Berg 1954, Idbohrn 1954, Sandström 1953). With direct puncture of the aorta, one can never be sure in advance where the tip of the needle will come in relation to efferent vessels; under unfavourable circumstances, large quantities of highly concentrated contrast medium may land in a narrow vessel with a relatively moderate flow of blood and cause organic damage which may prove lethal.

The need for more exact disposition of the contrast medium has produced methods by which catheters are introduced into the arteries or into the abdominal aorta.

Examples of these methods are Radner's technique (1951) with vertebral angiography, Fariñas' (1941) and Seldinger's system of retrograde catheterization of the femoral artery and the abdominal aorta (1953). In the latter case the catheter is inserted to what is assumed to be the origin of the vessel or vessels to be studied, *e. g.* the renal arteries. With this method both the quantity and the concentration of the contrast

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Fig. 1 (top). The point of the catheter.

Fig. 2 (below). Catheter with two-way stopcock and point.

medium could be decreased. At the same time, filling of the vessel branches on both sides could not be avoided. In many cases, however, more exact dosage would have been desirable, but this would have required deposition of the contrast fluid directly in the vessel concerned.

This problem can only be solved by using some form of guided catheter. In 1951, the writer described preliminary experiments using a catheter with a flexible point directed by a magnetic field. This method has now been further refined and also tested clinically, which is the reason for the present report.

The apparatus consists of an electromagnet placed under the examination table which must be of non-magnetic material. The magnet is mounted on a small carriage which can be moved both along the long axis of the table and at right angles to it. A roentgen tube with the beam in the horizontal plane and movable upwards and sideways is placed at one side of the table and directed at right angles to the table so that the patient may be irradiated from one side to the other. A movable fluoroscopic screen is placed on the opposite side of the table.

The magnet in question was constructed by ASEA, Västerås. It is in the form of a circular disc, 600 mm in diameter and approximately 250 mm in thickness. It can be charged with 80 volts and 100 amperes, which, however, has proved excessive; in most of the examinations the charge did not exceed approximately 25 volts and 30 amperes. New magnets could consequently be made considerably smaller and lighter.

The catheter is a 120 cm long cardiac catheter made of plasticized cloth. A No. 7 USCI X-Ray catheter was used in most of the experiments. The flexible point, approximately 35 mm in length (made by I. Peterson, Engelbrektsgatan 28, Västerås), and consisting of four cylindrical sections linked by ball-and-socket joints, is screwed to the extremity of the catheter (Fig. 1). Each joint permits a range of movement of 20 degrees in all directions. There is free passage through the entire point with funnel-shaped dilatations of the lumen in each joint so as to avoid obstruction to the unimpeded flow of the contrast medium if the point is bent at the moment of the injection. The point is made of soft iron, gold-plated to prevent rusting.

The catheter is fitted with a two-way stopcock. Heparinized physiologic salt solution is introduced into one side, while the contrast medium is injected through the other side (Fig. 2). To ensure a satisfactory speed, the injection of medium must be made under relatively high pressure, since the friction resistance in the long catheter and the point is considerable. With this in mind, an injection apparatus employing compressed air was constructed, and permits an injection pressure of as much as 30 kg per square centimeter. The injection pressure can be adjusted with a reducing valve so that the injection takes approximately 10 seconds.

Magnetic curves in a series of different geometric formations, from straight to strongly curved, exist in the magnetic field around a magnetic pole. The flexible point of the catheter behaves in the magnetic field in roughly the same way as iron filings and adjusts itself to the direction of the magnetic curves. Thus, by selecting a suitable part of the magnetic field, the point may be given almost any curvature desired and, by choosing the manner of introducing the point in the magnetic field, the direction of the concavity may be determined dorsally or ventrally. Since the point behaves consistently in the magnetic field, one soon learns to steer it at will under fluoroscopic control.

The patient is placed supine on the examination table with the left arm extended on an arm rest attached to the table. The radial artery is dissected free about ten centimeters distal to the flexure of the elbow, and the catheter inserted into the artery with the help of a special instrument. The entrance of the catheter into the descending aorta is then controlled on the fluoroscopic screen. This operation usually takes place without the help of the magnet, although the latter must sometimes be used even at this stage of the procedure. The examinations conducted hitherto have mainly consisted in angiography of the celiac trunk with its branches and of the renal arteries. In the former case, the point of the catheter is curved upward just as it reaches slightly above the diaphragm and is pushed down a few centimeters, whereupon it usually slips easily into the celiac trunk. By turning the point to the right or left immediately, it may be directed into the common hepatic artery or the splenic artery, provided of course, that these arteries actually originate in the celiac trunk in the case under examination.

The catheter is most easily introduced into the renal arteries with the patient lying on the same side as the kidney to be examined. When the catheter has been placed in the appropriate vessel, the contrast medium is introduced and, at the same time, the exposures are made. Very small amounts of contrast fluid may be used. Ten (10) ml of medium is usually sufficient for a satisfactory renal angiogram, while 15 ml is suggested

Fig. 3. Selective renal angiogram.

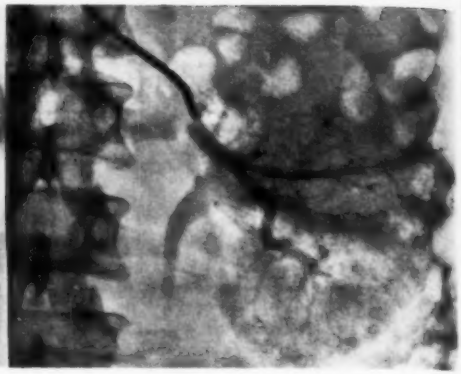

Fig. 4. Selective renal angiogram showing expanding process.

for a celiac angiogram. The concentration of medium neither need nor would exceed 35 per cent. The writer used Umbradil (Astra).

The vessel is sutured after completion of the examination. This is a simple procedure, and the radial pulse was maintained in all the cases in which the method was used. Even though ligation of the radial artery is not in itself of any great importance, it is an advantage to preserve the vessel, particularly in cases in which a second examination is required. A further examination was carried out in one case in which the suture was found to have healed well and the flow of blood unimpeded.

About 30 examinations have been carried out up to date, and in 20 cases the method described was used. On several occasions during the earlier examinations a spasm which appeared in the brachial artery prevented the examination from being carried through.

The 20 later examinations were made with no complications of any kind. The patients suffered scarcely any discomfort. In this connection, premedication seems to be of great importance.

In 7 of the 20 later examinations one of the kidneys was investigated and in six cases satisfactory angiograms were obtained. Thirteen examinations concerned the celiac trunk, and in eight cases selective angiograms of the trunk with its branches were obtained. In 1 case the catheter could only be directed into the superior mesenteric artery, and in 4 cases the examinations could not be completed, as the catheter could be directed neither down into the descending aorta nor up into the celiac trunk.

Premedication was confined to mild sedation and an intramuscular injection of 8 cg of papaverine sulphate 15 minutes before the examination was begun. Since the examinations to date were mainly intended to translate experimental findings into a practical clinical method, it seems

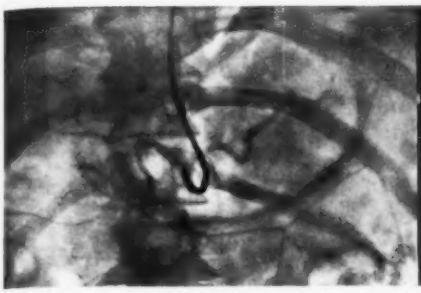

Fig. 5. Angiogram of the celiac trunk.

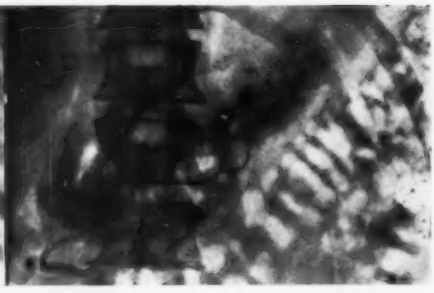

Fig. 6. Arterial angiogram of the pancreas.

unnecessary to discuss the cases at this time. It appears from those investigated up to now that selective renal angiograms may be made with relatively small quantities of contrast medium (Figs. 3 & 4) and that the celiac trunk is accessible to selective angiographic studies (Fig. 5). With the catheter in the gastroduodenal artery, I was able, in one case, to visualize the pancreas, which suggests new possibilities of diagnosis in that organ (Fig. 6).

Conclusions

So far the drawbacks of the method seem to be the rather complicated equipment and the surgical procedure required to introduce the catheter. Meantime, experiments are under way to try to simplify the method with percutaneous introduction of the catheter in the brachial or femoral artery. In renal angiography the presence of aberrant renal vessels may lead to filling defects in the renal parenchyma. The appearances, however, in these cases are highly characteristic.

The advantages of the method are inherent in the fact that only the organ to be studied is exposed to the trauma of the examination and that small, weak quantities of contrast medium may be used, thus permitting repeated angiograms to be made at the same examination. Furthermore the method seems to make it possible to examine otherwise inaccessible organs such as the pancreas.

Future experiments will be directed primarily at simplifying the technique and at increasing its clinical dependability. Special attention will also be paid to the possibility of arterial angiography of the pancreas and its diagnostic significance.

SUMMARY

The author describes experiments with directed angiography by means of catheters guided by a magnetic field. He discusses the possibility of selective renal angiograms and of arterial angiograms of the pancreas.

ZUSAMMENFASSUNG

Der Verfasser beschreibt Versuche mit gezielter Angiographie vermittels im Magnetfeld steuerbarer Katheter. Er diskutiert die Möglichkeit, selektive renale Angiographien und arterielle Pankreasangiographien auszuführen.

RÉSUMÉ

L'auteur décrit de nouvelles expériences d'angiographie dirigée au moyen de cathéters guidés par un champ magnétique. Il signale la possibilité d'angiographies rénales sélectives et d'angiographies artérielles du pancréas.

REFERENCES

Broman, T. & Olsson, O.: Experimental study of contrast media for cerebral angiography with reference to possible injurious effects on the cerebral blood vessels. Acta radiol. 31 (1949), 321.

Dos Santos, R.: Technique de l'aortographie. J. internat. chir. 2 (1937), 609.

Fariñas, P. L.: A new technique for the arteriographic examination of the abdominal aorta and its branches. Am. J. Roentgenol. 46 (1941), 641.

Idbohrn, H. & Berg, N.: On the tolerance of the rabbit's kidney to contrast media in renal angiography. Acta radiol. 42 (1954), 333.

Sandström, C.: Contrast media for the kidneys, heart and vessels and their toxicity. Acta radiol. 39 (1953), 281.

Seldinger, S. I.: Catheter replacement of the needle in percutaneous arteriography. Acta radiol. 39 (1953), 281.

Radner, S.: Vertebral angiography by catheterization. Acta radiol. Suppl. 87 (1951).

Tillander, H.: Magnetic guidance of a catheter with articulated steel tip. Acta radiol. 35 (1951), 162.

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RENAL PAPILLARY NECROSIS

by

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According to the literature, necrosis of the renal papillae is a relatively rare, almost invariably fatal disease. It has its highest incidence in elderly patients with diabetes mellitus or obstructive uropathy and is always associated with pyelonephritis.

Patho-anatomically, papillary necrosis has been known for a long time; it was briefly mentioned by ASCHOFF and KAUFFMANN.

FRIEDREICH (1877) was the first to give a clinical description of papillary necrosis. His patient was a man, aged 70, with a past history of good health, who was admitted in a cachectic condition, became increasingly drowsy and died 4 days after admission. All papillae of both kidneys were necrotic, although to a variable degree. The patient was non-diabetic, but had prostatic hypertrophy. SCHÖMER (1931) reported three cases: in a 68-year-old woman with carcinoma of the stomach and two men, both aged 48, all with infection of the urinary tract. One of the patients was diabetic. PRAETORIUS (1937) reported a case in a man, aged 57, who had for 7 months suffered from intermittent severe sepsis accompanied by fatigue, emaciation and left-sided pyuria. The patient was subjected to nephrectomy, and the kidney revealed a dilated pelvis with eroded ulcerating papillae, partially covered by pus. Signs of tuberculosis were absent. FROEBOSE (1937) was the first to emphasize the frequent occurrence of papillary necrosis in association with diabetes mellitus. He presented 10 cases, all in women, whose ages ranged from 39 to 82 and averaged 63 years. All except one had diabetes, mostly of several years' duration. All had severe infection of the urinary tract and died with signs of sepsis in hyperpyrexia. The spleen was infected and the kidneys revealed multiple medullary necroses.

GÜNTHER (1937) was the first to mention roentgen examinations in papillary necrosis; he emphasized that the diagnosis is difficult, although roentgenograms may sometimes be helpful. In 1948, GÜNTHER had observed 29 patients, of whom only four were non-diabetics. ALKEN (1938) performed nephrectomy in three out of four diabetic patients with pyelonephritis. Two of these showed large pyonephroses complicated by papillary necrosis, which was, however, not recognized until at the subsequent pathologic ex-

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amination. In the two other cases the diagnosis was made clinically. ALKEN emphasized the importance of persistent pain in the renal region, haematuria, and fever, but roentgenograms were also of value in making the diagnosis in these two cases. The roentgenographic findings were confirmed by operation in one case and by passage of necrotic papillary tissue in the urine in the other.

During the next few years the reports on papillary necrosis increased in number and contributed essentially to our understanding of this serious disease.

Pyelonephritis seems to be a necessary antecedent to papillary necrosis, and as pyelonephritis is common in diabetics, this accounts for the predilection of the necrosis for this category of patients. At autopsy, the incidence of pyelonephritis among diabetics ranges from 20 to 25 per cent, whereas the frequency of infection of the urinary tract is 3 to 4 per cent in unselected case materials.

EDMONDSON (1947) studied an autopsy series from Los Angeles consisting of 859 diabetic subjects. Pyelonephritis was revealed in 107 cases, and among these papillary necrosis was present in 29, or 27.1 per cent, viz. 19 women and 10 men. The affection was bilateral in 18 cases and unilateral in eight, while no information as to the involvement was given in the remaining three cases. Only one patient was under 40 years of age. In another autopsy series comprising 307 diabetic patients, 60 showed signs of pyelonephritis, including 16 with papillary necrosis (26 per cent). These two series of diabetics show an incidence of papillary necrosis of 3.4 and 5.2 per cent, respectively. In comparison, it may be stated that in large, unselected series comprising many thousand of autopsies (31,141), EDMONDSON found an incidence of papillary necrosis of 0.07 per cent. MANDEL (1952) collected 160 cases from the literature, including 96 diabetics. Obstruction to the passage of urine was found in 15 diabetic and 48 non-diabetic patients. Among 91 diabetics, four were under 40, 52 between 50 and 70, and 17 over 70 years of age. Among 62 non-diabetics, 11 were under 40, 22 between 50 and 70, and 20 over 70 years of age. Of the 91 diabetics, 66 were women, while the 62 non-diabetics comprised 45 men and 17 women. From Scandinavia, MELLGREN and REDELL (1941) reported two cases (a woman, aged 63, and a man, aged 74). Both patients had severe pyelonephritis with necrosis of most papillae. These patients were not diabetic; both died in uraemia. GAUSTAD and HERTZBERG (1950) mentioned six cases from Ullevål Hospital, four women and two men, whose ages ranged from 65 to 80 years. Five of these were diabetics and had pyelonephritis, three of them to a severe degree. In one patient the affection was bilateral and all papillae were necrotic. In four of the five unilateral cases all papillae were affected, while only three papillae were involved in the fifth. In all six cases, the diagnosis was not made until at autopsy.

Papillary necrosis is very rare in children and young adults. ARTUSI (1926) reported a case in a 3-year-old child, who died of haematogenic nephritis with papillary necrosis following angina. TAMAKI and WHITMAN (1952) observed papillary necrosis in an infant, aged 8 weeks, who died in uraemia in the course of a week. The infant was non-diabetic, and there were no signs of urinary tract obstruction. All papillae on both sides were necrotic.

Several cases have been reported from Denmark, most of them within the last year or so.

ESKELUND (1945) mentioned a woman, aged 55, who within the space of 3 years had repeatedly been admitted to hospital for treatment of pyelonephritis. She was readmitted for the same disease and was treated with sulphathiazole and granulated calcium mandelate, but the infection persisted; the temperature rose to 39—40° C, and the blood urea increased to 129 mg%. Treatment with alphasol produced some improvement. Retrograde pyelography (both sides on the same day) showed normal conditions. Immediately after this examination the disease flared up; the temperature rose,

the urinary output and specific gravity decreased, the blood urea increased to 230 mg%, and the patient died less than a month after the pyelography. Autopsy revealed small kidneys; all papillae on both sides were necrotic. ESKELUND expressed the view that it cannot be excluded that direct retrograde pyelography in this patient was the exciting factor in the development of papillary necrosis in the kidneys, which were already severely affected by pyelonephritis. ANTHONISEN (1953) mentioned three patients, two women, aged 77 and 62 years, and a man, aged 56. One of the women was diabetic, whereas the other two patients showed no signs of diabetes. All three succumbed. The diagnosis was made at autopsy. In all three cases, several papillae were necrotic, in two of them on both sides. LUNDBÆK (1954) reported two cases, both in women (70 and 71 years of age). One had suffered from diabetes for 16 years; this had become complicated by arterial hypertension, renal insufficiency, albuminuria, and coliuria. The other was non-diabetic, but suffered from pernicious anaemia and chronic pyelonephritis. Both died, and autopsy revealed necrosis of several papillae.

PETERSEN (1954) described two cases in non-diabetic women, aged 47 and 39 years. Both patients gave a history of urinary tract disease of long duration, with recurring fever, chills, anaemia, haematuria, dysuria, and pyuria suggestive of a severe infection, which had been responsive to antibiotic therapy only for a short time. Both patients underwent nephrectomy, which revealed chronic pyelonephritis and necrosis of several papillae. Operation produced some improvement but did not result in complete recovery; in both cases the infection had spread to the opposite kidney. PETERSEN stated that a total of 194 cases of papillary necrosis are on record, including 118 in diabetic patients. Urinary tract obstruction was encountered in 52 cases, while neither diabetes nor obstructive uropathy was present in 24.

The two cases reported by STARKLINT (1954) also occurred in relatively young women (39 and 47 years old), both without diabetes, but with pain in the lumbar region and acute uropathy. One of the patients had haematuria. As the disease was unilateral, both patients were subjected to nephrectomy, which seemed to result in recovery.

The majority of the cases reported in the literature occurred in patients of advanced age, particularly in diabetics and patients with urinary tract obstruction, and always in association with more or less severe pyelonephritis. The disease is rarely diagnosed during life and most frequently leads to death. Recent publications show that papillary necrosis may also be encountered in younger individuals without diabetes or obstruction to the urinary flow, and that active treatment (nephrectomy) occasionally seems to arrest the disease.

The signs and symptoms of papillary necrosis are the same as are seen in infections of the urinary tract.

The most frequent clinical observations are pain in the flanks, dysuria, an imperative desire to micturate, and pollakisuria; fever with chills, nausea and vomiting, oliguria, and anuria are also encountered.

Laboratory investigations may reveal albuminuria, pyuria, bacteriuria, and haematuria varying in degree from microscopic to massively macroscopic. Finally, azotaemia and hypertension may be demonstrated.

The infection is often caused by staphylococci or Esch. coli, but streptococci and proteus organisms have also been revealed. Actino-

mycosis has been found to be responsible for the necrosis in one case and tuberculosis in another.

The disease often begins as an acute fulminating septicaemia with rapidly progressive uraemia, which leads to death in the course of days or weeks. It may appear as an acute incontrollable exacerbation of an existing chronic pyelonephritis, terminating fatally within a few weeks. Finally, the disease may sometimes run a more chronic course with symptom-free intervals of varying lengths; in these cases the prognosis is less unfavourable, and the condition need not necessarily be fatal.

The diagnosis of papillary necrosis should particularly be considered in 1) diabetics who are attacked by a violent urinary tract infection of acute onset; 2) diabetics showing a sudden exacerbation of an existing pyelonephritis; 3) diabetics with renal colic, haematuria and uraemia; 4) non-diabetics with urinary tract obstruction and refractory pyelonephritis; finally, the diagnosis must also be considered in 5) non-diabetic patients without any obstruction to the urinary flow who present symptoms of prolonged, intermittent, and unexplained, pyelonephritis with frequent recurrences, possibly in combination with pain in the flanks and haematuria, but in whom the blood urea and blood pressure may be within normal limits.

Autopsy cases have shown that the necrosis may involve one, more than one, or all papillae; it may be either unilateral or bilateral. The necrosis may be confined to the papillary tip, or may involve the entire papilla. Grossly, a demarcation line of a whitish colour, 1 to 2 mm in width, may be seen. The necrotic papilla may be reddish, or brownish yellow, in older cases more a pale yellow, always strongly contrasting with the surrounding, more normally coloured tissue. The necrosis varies from the size of a hemp seed to that of a raisin and may be rounded or more oblong in form. After sequestration, the necrosis often remains in its cavity, in which it shrinks and is finally completely absorbed, but it may also be cast off, pass into the renal pelvis, and further through the ureter to the bladder, from which it may be voided in the urine. Calcium-encrusted necrotic papillae may simulate calculi. It may be added that patients who have died of other causes have, at autopsy, shown complete absence of papillae with smooth epithelization of the demarcation surface. This has been taken as evidence of spontaneous healing of the lesion.

Histologic examination shows complete necrosis of the papilla with pyknotic cell nuclei or absence of nuclei and total loss of cell structure. The demarcation zone is very sharp and contains numerous leukocytes and lymphocytes. Hyperaemia is usually present in the areas peripheral to the demarcation line. The parenchyma shows inflammatory changes of varying severity; small abscesses are occasionally present. Clusters of

bacteria and round cells are observed in the collecting tubules, and the blood vessels in the vicinity of the necrosis often reveal multiple thrombosis and arteriosclerosis. Finally, intercapillary glomerulosclerosis is frequently seen in diabetic subjects.

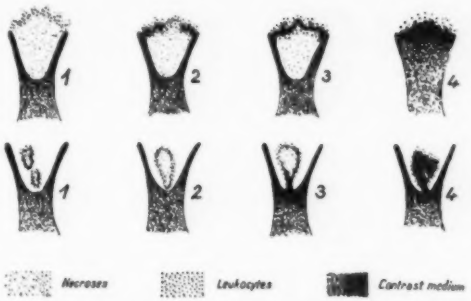

Fig. 1. Upper row: papillary necrosis. Lower row: medullary necrosis (after GÜNTHER).

The pathogenesis is obscure. Anatomic conditions may play a part. In this connexion it has been pointed out that the blood supply to the papillae and pyramids is less abundant than to the remaining parts of the kidney. Only a few small vessels branch off direct from the arciform arteries to the papillae.

The blood to the papillae must first pass the glomeruli, the peritubular capillaries and, finally, through the straight arterioles, which form few anastomoses, before it reaches the papillae.

Sclerotic arterial changes, often of a severe degree, which have been demonstrated in numerous cases, may also be a contributory factor in the development of necrosis.

As papillary necrosis is always associated with pyelonephritis, it is reasonable to assume that the necrosis is caused by bacteria or infection. The infection may be either haematogenic or canalicular. Especially in diabetics, haematogenic infection is said to be common. In some experiments in which the ureter was ligated and bacterial cultures injected into the closed urinary tract system, ALBERRAN showed that a purulent pyelonephritis, sometimes accompanied by papillary necrosis, developed in the course of 2 to 3 days.

The roentgen diagnosis of papillary necrosis is difficult and often impossible, but a precise knowledge of the pathologic anatomy and familiarity with the changes which may be expected may presumably ensure success. In his study of 1948, GÜNTHER published a diagram of the roentgenographic appearance of papillary necrosis (Fig. 1). GÜNTHER distinguished between two forms, *viz.* a) papillary necrosis and b) medullary necrosis. Stage 1 shows a necrosis which is demarcated by leukocytes, but not yet sequestrated. The contrast medium cannot penetrate into the space between the necrotic papilla and the viable tissue; hence the roentgenogram cannot be expected to be informative. Our Case 6 is a representative of this stage. After resection of the upper renal pole, inspection revealed necrosis of the upper papillae, which were demarcated but not sequestrated; the separation was not yet complete. On uro-

Fig. 2. Case 6. Unsatisfactory filling of upper part of renal pelvis. Papillary necrosis Stage 1.

Fig. 3. Case 3. Ring shadow (sling figure) in inferior calyx. Papillary necrosis Stage 3.

graphy there was no excretion in the upper calyces, whereas the central and inferior calyces showed good function. Retrograde pyelography demonstrated good filling of the renal pelvis and the central and inferior calyces, which all appeared normal with well-defined contours. Filling of the proximal calyces was also obtained, but the distribution of the contrast medium was less satisfactory; the calyces failed to fill regularly and did not show the same sharp contours as seen in the other regions (Fig. 2). A definite diagnosis of papillary necrosis was not made, but one of localized pyelitis, which later appeared to be pyelonephritis with papillary necrosis. As can scarcely be expected, a detailed differential diagnosis is not obtained in these early cases, but the combined roentgen examination with urography and retrograde pyelography may occasionally be helpful in localizing the affection. However, in many of these cases in which only one or two papillae are necrotic and have not yet been cast off, the roentgenographic appearance is perfectly normal.

Stage 2 in GÜNTHER's diagram shows incipient sequestration giving a possibility of inflow of contrast medium into the zone of demarcation,

Fig. 4. Case 1. Ring shadow (sling figure) in inferior calyx on left side demonstrated urographically. Papillary necrosis Stage 3.

but here, too, the roentgenographic changes will be inconspicuous and questionable, so that the film cannot be expected to be more informative than in the preceding group of cases.

Our Case 3 is an example of this stage; a urogram taken on 17 November 1953, revealed in the inferior calyx an opacity surrounding a zone of lessened density, the size of a raisin, the so-called 'ring shadow' which is fairly typical and presumably the most definite sign of papillary necrosis (Fig. 3). A renewed study of previous films revealed that this opacity had also been present three months before, but was then less distinct and had therefore escaped recognition. The changes had thus been present for three months, or presumably more, which shows that the separated necrotic papilla may remain in its cavity for a long period.

Case 1 is another example of the same roentgenographic change; a urogram taken on 5 January showed a similar ring shadow in the distal part of the left kidney (Fig. 4). These changes could not be visualized by direct pyelography on the 12th (Fig. 5), but were seen again in a urogram taken on 14 January.

Case 4 is a third example of the presence of a ring shadow which was shown in the second calyx from below in the left kidney by retrograde pyelography (Fig. 6), but could not be demonstrated in the urogram, in which very sparse excretion was evident on the left side.

Fig. 5. Same case as Fig. 4. No sling figure by direct pyelography.

Fig. 6. Case 4. Sling figure in second calyx from below by direct pyelography. Papillary necrosis Stage 3.

In all three cases, partial resection of the lower renal pole was performed, and isolated papillary necrosis disclosed (Fig. 7). It has been claimed that retrograde pyelography should be best suited to reveal the necrosis, and this was true in Case 4, where the changes were demonstrated only by this method of examination. On the other hand, retrograde pyelography failed in Case 1, in which the necrosis was visualized only in the urograms. Finally, in Case 3 the changes were most distinct in the urogram, but were also seen in the pyelogram. In other words, it is not enough to rely on one of these methods; if papillary necrosis is suspected, both methods of examination must be used. It must be emphasized that the greatest care should be exercised in these examinations. They should preferably be carried out under fluoroscopic control in order to graduate the contrast injection, so that the proper degree of filling is obtained and visualization of all the calyces ensured by taking films at different angles.

GÜNTHER's Stage 4 is represented by our Case 7 (Fig. 8) in which the inferior calyx on the left side showed, in three different urograms, a contrast-filled, bean-sized cavity with a peripherally convex, fairly well-

defined margin instead of the usual cup-shaped opacity. This alteration had also been present for a long time. The resected specimen showed flattening of the papillary tip.

Stages 1 and 2 in GÜNTHER's diagram show medullary necroses cut off from the papillary surface, while Stages 3 and 4 present somewhat larger medullary necroses in contact with the renal pelvis; this makes it possible for the contrast medium to penetrate into the papilla and reveal the presence of necrosis. Examples of medullary necrosis did not occur in our series, but GÜNTHER published a roentgenogram which was stated to be typical of medullary necrosis.

Fig. 7. Case 1. Resection specimen. Isolated papillary necrosis.

In the *differential diagnosis* the backflow phenomenon occupies a prominent position. This phenomenon was described in detail by OLSSON (1948). Backflow occurs when the fornix wall ruptures on account of excessive pressure in the renal pelvis, and may be seen both in urography with compression and in retrograde pyelography. Backflow may also occur in urography without compression in patients with renal colic in the acute stage. Fornix-sinus backflow is the most common form and occurs when the contrast medium enters the sinus through fornix rupture and collects in the tissues outside a minor calyx.

Pyelolymphatic backflow begins in the same way; the contrast medium first enters the sinus and then travels along the lymphatics. This form appears in the roentgenogram as fine streaks of contrast medium running first medially, and later caudally.

The rarest form is pyelovenous backflow, which is hardly ever seen, since the contrast medium is rapidly carried away by the blood stream.

Pyelolymphatic or pyelovenous backflow will scarcely be mistaken for papillary necrosis, whereas fornix-sinus backflow may present difficulties in the differential diagnosis between medullary and papillary necrosis.

The calyceal diverticulum is a small, pea-sized cavity, usually arising from a minor calyx to which it is connected by a narrow isthmus. It is

Fig. 5. Same case as Fig. 4. No sling figure by direct pyelography.

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Fig. 8. Case 7. Contrast-filled bean-sized cavity peripherally to inferior calyx. Papillary necrosis Stage 4.

lined by the same epithelium as the renal pelvis (transitional epithelium), contains urine, and is usually asymptomatic (Fig. 9).

Roentgen examination fails completely in the early stages and presumably also frequently in cases of pure medullary necrosis. The most definite sign is the ring shadow, which occurs when the necrosis has become completely separated but still remains *in situ*. The flask-shaped distention of the calyx, which is seen when the necrosis has left its cavity, may also point to the correct diagnosis.

Case reports

Table 1 is a tabulated survey of eight cases of papillary necrosis seen in this hospital. All the patients were women; their age ranged from 29 to 57 and averaged 46 years. All showed signs of pyelonephritis; one was diabetic and two had obstructive uropathy. Except in Case 4, the blood urea and blood pressure were within normal limits. Four were subjected to resection and the remaining four to nephrectomy. Follow-up examinations showed that six must be supposed to have been cured, while two (Cases 4 and 6) still showed signs of infection. The histories of Cases 1 and 3 are reported as typical of isolated papillary necrosis.

Case 1. A woman, aged 34, had had coxa plana (Calvé-Perthes' disease) as a child and had suffered from diabetes mellitus for which she had repeatedly been treated since the age of 17. During the last year the patient had had 6 to 7 attacks of oppressive pain in the left renal region, accompanied by high fever (40 to 41° C). There had been no dysuria, haematuria, or pollakisuria. The last attack had occurred shortly before the first examination in this hospital. Pyuria, persisting in spite of terramycin therapy, had been disclosed. When first seen (31 December 1953), the only abnormalities were pyuria (catheterized urine) and glycosuria.

Urography (5 January 1954): Normal excretion of contrast medium on both sides with good filling, with the exception of the inferior calyx on the left side, which revealed changes suggestive of papillary necrosis.

The patient was admitted to the Department of Surgery D. Physical examination did not show any abnormalities; blood pressure 90/70; normal electrocardiogram; blood urea 20 mg%.

Fig. 9. Diverticulum in the upper of two lateral calyces.

Cystoscopy (12 January): Bladder capacity 300 ml. Catheterized urine clear. The mucosa was injected, in some places covered with fibrin. No ulceration or tumour. The ostia showed normal position and normal function. A catheter could be passed up for 25 cm on the left side.

Retrograde pyelography on the left side: The cavity just distal to the inferior calyx failed to fill, otherwise nothing abnormal. Further urography with compression and tomography (14 January): All calyces except the inferior on the left side were normal. Distal to the latter there was a bean-sized, slightly irregular, moth-eaten contrast shadow

Table 1

Case	Sex	Age	Pyelo-nephritis	Diabetes	Haematuria	Obstruction	Bacteria	Blood urea, in mg%	B. P.	Treatment
1	F	34	+	+	—	—	—	20	90/70	Resection
2	F	46	+	—	+	Vas aberrans	Coli Proteus	20	110/70	Nephrectomy
3	F	41	+	—	+	—	Coli	18	110/80	Resection
4	F	52	+	—	+	—	Coli	58	150/75	Resection
5	F	29	+	—	—	Ureteral stricture	Coli	39	110/65	Nephrectomy
6	F	37	+	—	+	—	Coli Proteus	30	100/65	Resection
7	F	49	+	—	+	—	Coli	20	100/60	Nephrectomy
8	F	57	+	—	—	—	Coli	40	110/80	Nephrectomy

with a small area of lessened density. After evacuation, there was retention in the small cavity. A diagnosis of papillary necrosis was suggested.

The urine was examined three times; it was negative for tuberculosis by direct microscopy and by culture and inoculation into guinea pigs.

Operation (20 January): Resection of the left kidney was performed under combined anaesthesia. The lower renal pole with the inferior calyceal system was resected under manual compression of the pedicle. The specimen removed comprised the lower renal pole. On section, the papillary tip revealed a cavity, the size of a kernel of a hazelnut, with a free opening to the calyx. The surrounding renal tissue appeared to be normal.

Histologic examination (SCHOURUP): Several sections were made from the renal tissue submitted. Some of them showed the renal pelvis with calyces. The transitional epithelium was preserved, with underlying, fairly pronounced round-cell infiltration. There were also a few papillary tips with mild inflammatory infiltrations in the form of scattered leukocytes along the ducts; in one place this phenomenon was, however, very pronounced. The papillary structures were otherwise preserved, and there were no signs of necrosis. Sections from the remaining part of the parenchyma, particularly the cortex, showed that the tissue was, on the whole, well preserved with normal glomeruli. Scattered in this tissue, there were, however, areas with more or less pronounced fibrosis both in the glomeruli and the pertinent tubules, and the cicatricial connective tissue showed fairly widespread round-cell infiltrations. Apart from these more or less streaky changes with corresponding retractions on the surface, the renal tissue submitted did not reveal pathologic processes. There were no signs of specific inflammation or malignancy.

Histological diagnosis: Subacute and chronic pyelonephritis.

Apart from some transitory difficulty in urination, the post-operative course was uneventful. No residual urine was present on 8 February and the patient was discharged three days later. The patient died after a traffic accident in another hospital on 9 December 1954.

Abstract from the autopsy record of the Institute of Forensic Medicine: The right kidney was normal, whereas the left kidney was relatively small, measuring about 9 cm in length. The lower renal pole was absent. The surface was smooth, apart from one cicatricial retraction. The renal pelvis and the ureters were normal.

Case 3. A woman, aged 41, suddenly fell ill with high fever (40° C), headache, vomiting, diarrhoea, bilateral lumbar pain, and pollakisuria, but there was no dysuria. She was admitted on 2 February. Blood urea and blood pressure were within normal limits. Cystography and urography did not reveal any abnormalities. Antibiotic therapy was instituted.

The patient improved and was discharged on 11 April, but the infection of the urinary tract remained unexplained; a focus in the left kidney was suspected, mainly because the patient complained of pain in that region. She was re-admitted on 17 April, again with high fever (40° C) and constant pain in the left lumbar region; there was no dysuria. The temperature returned to normal after treatment with chloramphenicol and streptomycin.

On 24 April, the patient was transferred to the Department of Urology D. The temperature was now 37.3° C and physical examination did not reveal any abnormalities. Blood urea 18 mg%; the urine contained a few leukocytes, but was negative for albumin and sugar; blood pressure 110/80. Gynaecologic examination showed nothing abnormal.

Urograms on 25 April showed normal conditions; there were no signs of calculi. Urine from the left kidney was cloudy and contained numerous leukocytes, a few erythrocytes, and epithelial cells and nümerous rods. Urine from the right kidney did not contain pathologic elements, and inoculation produced no growth.

Retrograde pyelography on the left side showed normal conditions.

During the next few days the patient was treated with irrigation of the left renal pelvis with saline and chloramphenicol, four times in all.

On 6 May, the patient passed a tissue particle, the size of an orange pip, in the urine. Histologic examination revealed that it was a necrotic papilla. Culture and inoculation of urine from the left kidney produced no growth and was negative for tuberculosis.

Even though there were still leukocytes in the urine and the diagnosis of papillary necrosis had been confirmed, the patient was nevertheless discharged with a normal temperature on 13 May. She had no symptoms for a few days, but then fever and pollakisuria returned, and she was re-admitted on 18 May. No abnormalities could be demonstrated. On discharge on 12 June, the patient was symptom-free with sterile urine.

Throughout the summer, the urinary tract infection re-occurred and was treated with antibiotics, mandelic acid, and autovaccine without beneficial effect. As the patient found her condition unbearable, she was re-admitted on 10 November for surgical treatment. By that time the patient had been subjected to urography on four occasions and to retrograde pyelography combined with tomography once, but these examinations had failed to disclose any abnormalities. On 17 November she was subjected to urography for the fifth time; the right side again showed normal conditions, but on the left side there was a pea-sized ring shadow just below the inferior calyx, close to the outer contour of the kidney.

A further examination of previous films showed that this ring shadow had been present previously, and that is was of the same size and situated in the same region. As we were not quite familiar with the picture at that time, the changes were interpreted as an abscess cavity forming the focus of infection.

Resection of the left kidney (November): Some adhesions around the kidney, which otherwise appeared to be normal in shape and size. The kidney was freed. As it looked normal, some doubt was entertained whether nephrectomy or only resection should be performed. As the focus was in the distal part of the kidney, it was decided to resect the lower pole. The specimen removed comprised the lower pole in the central part of which was a cavity containing a small piece of tissue resembling a necrotic papilla.

Histologic examination (SCHOURUP): Several sections were prepared from the renal tissue submitted. In some places, the tissue was perfectly normal with well-preserved glomeruli and tubules with normal epithelium. However, scattered in the normal tissue there were also some streaky areas of varying size which were the site of considerable interstitial fibrosis and contained a large number of rounded and migratory cells; the specific parenchyma showed degenerating glomeruli and tubules without epithelial lining containing casts in the lumina. These changes, which extended downwards towards the pelvis, were similar to those seen in pyelonephritis. In one place, there was a fragment of a calyx which showed inflammatory changes. In some areas papillary tips were seen in the sections, but these did not reveal changes which could be interpreted as papillary necrosis. There were no signs of specific inflammation or malignancy. A histologic diagnosis of acute pyelonephritis in chronic fibrosis was made.

The postoperative course was uneventful, and the patient was discharged a fortnight later. At a follow-up examination in January 1955 (14 months after operation), the patient was fully recovered. She had not had fever or suffered from dysuria in the meantime. A specimen of catheterized urine in March 1955 was acid and clear and contained no pathologic elements; no growth on inoculation.

Our cases of papillary necrosis were somewhat dissimilar to those previously reported. They all occurred in women, mostly in the younger age groups. One patient had diabetes and two obstructive uropathy.

The necrosis seems to have been isolated, and none of the cases terminated fatally. The patho-anatomic element of the disease was demonstrated in all cases, and the correctness of the diagnosis cannot be doubted.

The disease ran a course similar to that seen in other cases of complicated pyuria (calculi, hydronephrosis), and we interpreted the necrosis as a focus which maintained the infection. If this focus is eliminated, there should be a reasonable chance of recovery.

We found that surgical treatment should be given a trial in these cases in which conservative therapy proved unsuccessful. The experience gained seems to warrant a certain amount of optimism, and we intend to continue on the same lines. Time will show if our views are justified or not.

SUMMARY

Necrosis of the renal papillae is a rare, almost invariably fatal disease, which has its highest incidence in elderly patients with diabetes mellitus or obstructive uropathy and always occurs in association with pyelonephritis. The roentgenographic appearances are discussed in detail, and difficulties encountered in the differential diagnosis pointed out.

Eight cases are described. Four patients were subjected to nephrectomy and the remaining four to resection. Follow-up examinations showed that six must be supposed to have fully recovered, while two retained signs of infection.

ZUSAMMENFASSUNG

Nekrose der Nierenpapillen ist eine seltene, fast immer tödliche Erkrankung, die man am häufigsten bei älteren Patienten mit Diabetes mellitus oder obstruierender Uropathie findet und die immer zusammen mit einer Pyelonephritis auftritt. Das röntgenologische Aussehen wird genauestens diskutiert und die Schwierigkeiten, denen man bei der Differentialdiagnostik begegnet, werden hervorgehoben.

Es werden 8 Fälle beschrieben. Vier Patienten wurden nephrektomiert und die übrigen 4 reseziert. Nachuntersuchungen ergaben, dass 6 als völlig wiederhergestellt angesehen werden müssen, während bei 2 noch Anzeichen einer Infektion vorlagen.

RÉSUMÉ

La nécrose des papilles rénales est une affection rare, presque invariablement mortelle, qui s'observe le plus souvent chez des malades assez âgés atteints de diabète sucré ou d'affection obstructive des voies urinaires et se présente toujours associée à une pyélonéphrite. Les auteurs étudient en détail ses aspects radiographiques et insistent sur les difficultés rencontrées dans son diagnostic différentiel.

Ils en présentent huit cas. Quatre malades ont subi une néphrectomie et les quatre autres une résection. Les examens ultérieurs ont montré que six doivent être considérés comme ayant complètement guéris alors que deux ont gardé des signes d'infection.

REFERENCES

Alken, C. E.: Die Papillennekrose. Ztschr. f. Urol. 32 (1938), 433.
— Demonstration eines Falles von Papillennekrose. Ztschr. f. Urol. 33 (1939), 254.
— Zur Frage der Papillitis nekroticans. Ztschr. f. Urol. 33 (1939), 254.

ANTHONISEN, P.: Papillitis necroticans renalis. (Danish.) Ugesk. f. læger 115 (1953), 1971.
ARTUSI, G.: Über einen Fall von postanginöser Pyurie mit nekrotisierender Nephritis papillonis embolica. Beitr. z. path. Anat. u. z. allg. Path. 75 (1926), 1.
EDMONDSON, H. A., MARTIN, H. E., and EVANS, N. G.: Necrosis of renal papillae and acute pyelonephritis in diabetes mellitus. Arch. Int. Med. 79 (1947), 148.
ESKELUND, V.: Necrosis of the renal papillae following retrograde pyelography. Acta radiol. 26 (1945), 548.
FRIEDREICH, N. v.: Über Necrose der Nierenpapillen bei Hydronephrose. Virchows Arch. f. path. Anat. 69 (1877), 308.
FROBOESE, C.: Über sequestrierende Marknekrosen der Nieren. Verhandl. d. deutsch. path. Gesellsch. 30 (1937), 431.
GARRETT, R. A., NORRIS, M., and VELLIOS, F.: Renal papillary necrosis. J. Urol. 72 (1954), 609.
GAUSTAD, V., and HERTZBERG, J.: Acute necrosis of the renal papillae in pyelonephritis, particularly in diabetics. Acta med. Scandinav. 136 (1950), 331.
GÜNTHER, G. W.: Die Mark- und Papillennekrose der Niere, Pyelonephritis und Diabetes. Ztschr. f. Urol. 41 (1948), 310.
– Die Papillennekrose der Niere bei Diabetes. München. med. Wchnschr. 84 (1937), 1695.
LUNDBÆK, K.: Papilnekrose. (Danish.) Ugesk. f. læger 116 (1954), 136.
MANDEL, E. E.: Renal medullary necrosis, Am. J. Med. 13 (1952), 322.
MELLGREN, J., and REDELL, G.: Zur Pathologie und Klinik des Papillitis necroticans renalis. Acta chir. Scandinav. 84 (1941), 439.
NEWMAN, H. R., LOWMAN, ROB. M., and WATERS, L.: The problem of calyceal diverticulum. Surg., Gynec. & Obst. 94 (1952), 77.
OLSSON, O.: Studies on back-flow in excretion urography. Acta radiol. Suppl. 70 (1948).
PETERSEN, GORM: Papillitis necroticans renalis. (Danish.) Ugesk. f. læger 116 (1954), 939.
PRAETORIUS: Papillitis necroticans bei schwerer, chronischer Pyelonephritis. Ztschr. f. Urol. 31 (1937), 298.
SCHÄMER, W.: Capillarmetastatische Merknekrosen der Nieren. Frankf. Ztschr. f. Pathol. 41 (1931), 265.
STARKLINT, H.: Papillitis necroticans renalis. (Danish.) Ugesk. f. læger 116 (1954), 949.
TAMAKI, H. T., and WHITMAN, M. A.: Hemorrhagic papillary necrosis of the kidney. J. A. M. A. 150 (1952), 1304.

FROM THE DEPARTMENT OF CHEST DISEASES (PAB. 27) (DIRECTOR: PROF. A. CELIS), GENERAL HOSPITAL, MÉXICO, D. F.

LOBAR AND SEGMENTAL ANGIOPNEUMOGRAPHY IN PULMONARY DISEASE

by

Raúl Cicero and *Hermilo Del Castillo*

The angiopneumographic study of the alterations present in the vascular tree in pulmonary disease has provided extensive information on several aspects of the anatomy and physiology of the respiratory system.

CARVALHO et coll. (4) have, since 1932, studied the most outstanding changes of the pulmonary circulation in tuberculosis. CELIS et coll. (6) and RÍMINI et coll. (13) described the correlation existent between the bronchospirometric data and the angiopneumographic appearances in tuberculous lungs. STEINBERG (15) and DOTTER (9) pointed out the usefulness of angiopneumography in cases of primary cancer of the lung. One may conclude from these authors that the vascular alterations are, in the majority of cases, of great importance.

Attempts had been made by several investigators to develop better methods of rendering the lesser circulation opaque. CELIS et coll. (5, 6), by means of angiopneumography performed through direct catheterization of the heart chambers (global angiopneumography), obtained a very clear representation of the pulmonary vessels. BOLT and RINK (3), catheterizing directly the segmental arteries of the lung (selective angiopneumography), obtained angiograms in which the vascular pattern could be observed with the greatest accuracy; this was confirmed by BLUM and QUARTZ (2). JÖNSSON et coll. (10) previously demonstrated the clinical advantages of the selective technique and its diagnostic value in cases with stenosis of the main pulmonary artery.

The circumstances under which a roentgenogram is obtained are different for each one of these procedures. While, in the global angiopneu-

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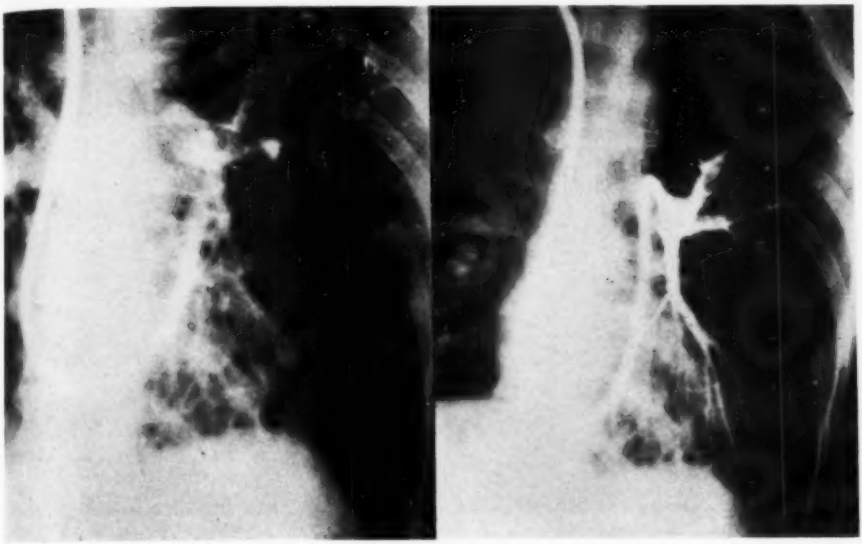

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Fig. 1. Cystic bronchiectasis of the left lower lobe. a) Global angiopneumography: Few arterial branches in the affected lung. b) Selective angiopneumography: The vessels are small and have no finer arborizations.

mographic method, the contrast substance mixed with the blood follows the most patent way into the pulmonary arterial tree, in the selective, it is injected into a pulmonary segment at a higher pressure. However, this fact does not completely explain the differences present between the global and selective angiograms obtained in the same patient; certain anatomico-pathologic processes combined with functional changes in the diseased lung parenchyma, undoubtedly also play an important rôle in determining these differences.

Our work is based on the observation of 146 angiopneumographic studies, global and segmental, carried out in 137 patients suffering from various pulmonary diseases. In 19 patients, only the selective study was performed.

The angiopneumograms were obtained with special reference to the pulmonary vessels. We used direct catheterization through the external jugular vein, following the technique described by CELIS (5). The selective angiograms were taken by the procedure used by BOLT and RINK (3). We employed rubber catheters (Levine type nos. 12—14 Fr.) for the global, and cardiac catheters (nos. 10—9 Fr.) for the selective angiopneu-

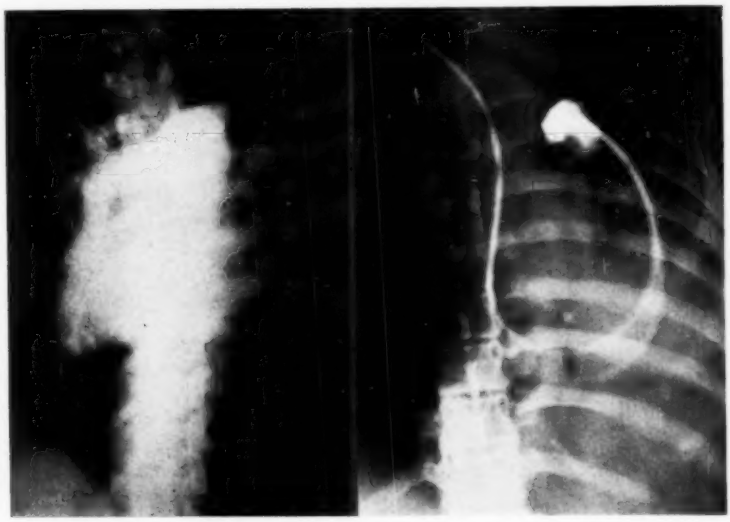

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Fig. 2. Tuberculous fibrothorax. a) Oblique angiocardiogram showing the origin of the left main artery. b) Direct catheterization of the left lung, showing the artery without segmental branches.

mographies. The contrast medium used was Nosylan (diodrast) 70 %, and the amount injected 8 to 15 ml, in accordance with the extent of the region to be studied. The exposure was made immediately at the end of the injection. High voltage technique was found to be the most useful for this kind of work.

In one case, after the injection, there was hemoptysis (3 to 4 ml of blood); we believed that the catheter was in the left main artery, whereas, in fact, it lay in a segmental branch.

I. Comparative date on global and selective angiograms. It is possible to find important differences between the appearances in the same individual. Some arterial branches are not clearly outlined with the global method, but when the selective procedure is used, these become apparent, particularly in the case of bronchiectatic lungs (Fig. 1). Nevertheless, the most clear examples are found in tuberculous lesions and in the lobes remaining after pulmonary resection.

STEINBERG and ROBB (14), point out the possibility that, in cases of fibrothorax, the apparent absence of pulmonary arteries on the affected side could be due to the position in which the angiopneumography was performed. Their angiograms are not precise, due to the fact that they

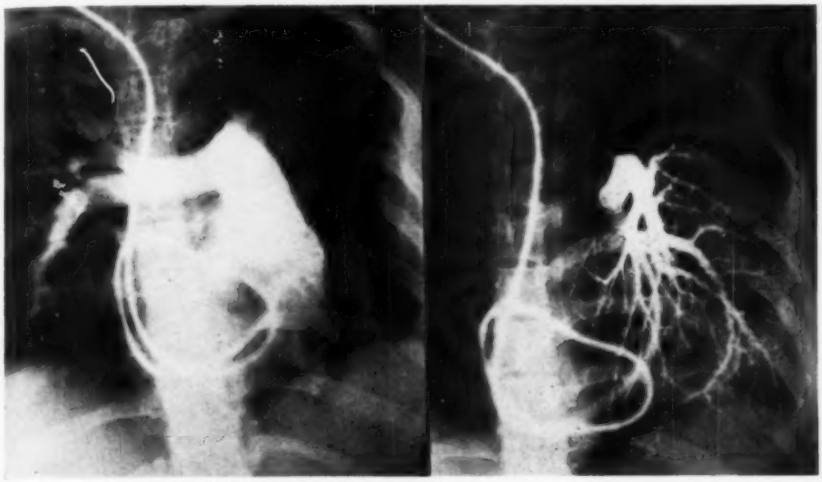

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Fig. 3. Left upper lobe resected. a) Global angiopneumography shows diminished arborization of the left lower lobe. b) Selective angiopneumography demonstrates the arterial tree of the remaining lobe with finest details.

used the global method, injecting the contrast medium through a vein of an arm; dilution is an important factor to be considered and for this reason, the detail of the vascular structures was not completely satisfactory.

In a previous study on tuberculous fibrothorax (7), selective angiopneumography showed us that there are important alterations of the vascular pattern in the affected lung; these could not be demonstrated by the global method (Fig. 2). The comparison of angiograms in lungs affected by advanced tuberculosis, taken in the same individual during life and post mortem, also showed important differences; these were due to the injection of the contrast medium having been performed in necropsy specimens at a higher pressure than during life (8).

The arteries may undergo important pathologic changes, mainly consisting of proliferation of the muscular layer. These were observed especially in tuberculosis and pulmonary fibrosis; the total obliteration of the vessels is not rare. Under these circumstances, the vascular resistance to the blood flowing through the diseased lung parenchyma must be higher, the circulation through such an altered pulmonary tissue being diminished and in some regions nonexistent. For this reason, global angiopneumograms fail to outline vessels which, however, may be visualized when the radiopaque substance is injected at a higher pressure than

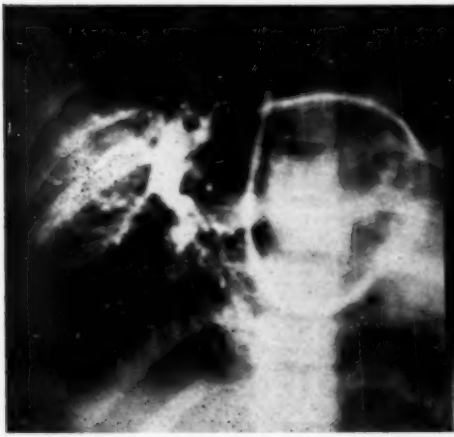

Fig. 4. Right lower lobe infarct. Absence of a few segmentary branches in the thrombosed area.

Fig. 5. Chronic caseocavernous tuberculosis. Complete absence of the upper arterial branches; the lower segmentary vessels are small and distorted.

Fig. 6. Early tuberculosis of the left upper lobe. Normal vascular pattern of the apical segment in the upper lobe; the corresponding venous return flow can be seen.

Fig. 7. Hematogenous tuberculosis. Normal posterior segment of the left upper lobe; the segmentary vein is clearly seen.

Fig. 8. Large cavity in the right upper lobe. Selective angiopneumography shows complete absence of arteries.

that existing in the pulmonary arterial tree. The mechanical obstacle is explained by the pathologic alterations of the vascular structures, mainly obliterating processes, as previously mentioned by Bolt and Rink (3) and by Cicero and Celis (8).

In cases in which pulmonary resection has been performed, some authors consider that the angiopneumogram has a physiologic foundation (11, 12). In the hemithorax in which the remaining lobe shows a diminution of vascular arborization, the oxygen uptake is also diminished. If the remaining lobe is over-distended, the vascular resistance to the blood flow is increased. Selective angiopneumography makes possible the anatomic diagnosis of the arterial tree; in these cases distortion is frequently found in the segmental and subsegmental ramifications (Fig. 3). The differences observed between the two angiograms may be due to the increased resistance to the circulating blood, although the arteries may be normal from the histologic point of view.

II. Findings in selective angiopneumography. Segmental and lobar angiopneumograms offer important data on the anatomic condition of the arterial arborization. These findings may be due to various factors present in the diseased lung parenchyma.

The most clear example of a mechanical obstacle may be seen in cases with pulmonary infarction in which the total absence of any arterial

Fig. 9. Same case as in Fig. 8. The lower branches are also altered.

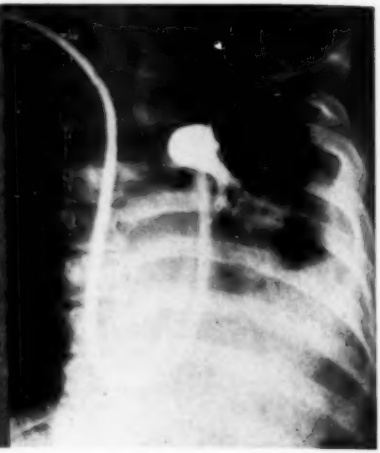

Fig. 10. Fibrocavernous tuberculosis. The left main artery shows only a few branches remaining in the lower lobe.

filling in the affected region may be encountered; this would be caused by a thrombus situated in the lumen of the artery and obstructing the blood circulation (Fig. 4).

In chronic pulmonary tuberculosis, the angiographic alterations are secondary to the pathology of the vessels. In the caseopneumonic processes with large cavities, the changes observed in the arterial branches are very important (Fig. 5), and we have never seen the corresponding veins in the same roentgenogram. This fact may be due to slowing of the blood circulation within the affected region as previously mentioned by BLUM and QUARZ (2) in a seriographic study performed by selective angiopneumography on tuberculous lungs. On the other hand, in early and miliary tuberculosis, the segmental branches have a normal appearance and it is possible to visualize the corresponding venous circulation, as in normal lungs (Figs. 6 and 7). In these cases, vascular alterations do not exist at this stage, and, according to several investigators recently quoted by ANNO and TOMASHEFSKY (1), the circulation continues through the diseased regions with poor ventilation.

In cavernous lesions, selective angiopneumography shows that there is no arterial arborization; only a few thin and distorted vessels surrounding the walls of the cavities may be seen (Figs. 8, 9, and 10).

Acknowledgment

We wish to thank A. Palma of the Roentgen Department of the General Hospital for his kind help.

SUMMARY

Angiopneumography by the selective method permits the anatomic study of the pulmonary vessels with the greatest accuracy. Vascular resistance to the blood flow may be one of the most important factors in determining some of the differences observed between global and selective angiopneumographies. For this reason, a comparison between the two procedures in the same individual gives information on the type of the changes present in the diseased lung parenchyma.

ZUSAMMENFASSUNG

Die selektive Angiopneumographie gestattet es, das anatomische Studium der Lungengefässe mit grösster Genauigkeit durchzuführen. Der Gefässwiderstand gegenüber dem Blutstrom dürfte einer der wichtigsten Faktoren für die Feststellung einiger der Unterschiede sein, die zwischen der globalen und der selektiven Angiopneumographie beobachtet worden sind. Aus diesem Grunde gibt ein Vergleich dieser beiden Prozeduren bei ein und demselben Individuum Auskunft über den Typus der in dem erkrankten Lungenparenchym vorhandenen Veränderungen.

RÉSUMÉ

L'angiopneumographie par la méthode sélective permet l'étude anatomique des vaisseaux pulmonaires avec la plus grande exactitude. La résistance vasculaire à l'écoulement du sang pourrait être un des facteurs les plus importants pour expliquer certaines des différences observées entre les angiographies globales et sélectives. C'est pourquoi la comparaison des deux méthodes chez le même individu renseigne sur le type des altérations présentes dans le parenchyme pulmonaire malade.

REFERENCES

1. Anno, H. and Tomashefski, J.: Studies on the impairment of respiratory function in pulmonary tuberculosis. Am. Rev. Tuberc. 71 (1955), 333.
2. Blum, W. and Quarz, W.: Zur Morphologie der Lungentuberkulose beim Vergleich von Bronchogramm und Angiogramm. Beitr. z. Klin. Tuberk. 109 (1953), 528.
3. Bolt, W. H. and Rink, H.: Selektive Angiographie der Lungengefässe bei Lungentuberkulose. Schweiz. Ztschr. Tuberk. 8 (1951), 380.
4. Carvalho, L. De, Moniz, E. and Almeida, L.: L'angiopneumographie et son application dans la tuberculose pulmonaire. Presse méd. 40 (1932), 1098.
5. Celis, A.: Angiocardiografía. Nota preliminar sobre un método personal. Rev. méd. d. Hosp. gen. 8 (1946), 1101.
6. — Avila, A., Nava, J., Pacheco, C. R., Portales, H., Villalobos, M. E. and Del Castillo, H.: Estudios sobre la función cardiorespiratoria de la tuberculosis. Rev. méd. d. Hosp. gen. 13 (1950), 130.

7. Cicero, R., Del Castillo, H., Fernández, V. M. and Moulún, M.: Selective angiopneumography in tuberculous fibrothorax. VI. Congr. Nal. de Tub. y Silicosis, México (1955).
8. — and Celis, A.: Antemortem and postmortem angiography of the pulmonary arterial tree in advanced tuberculosis. Am. Rev. Tuberc. 71 (1955), 810.
9. Dotter, Ch. T. and Steinberg, I.: Angiocardiography. Ann. Roentgenol. Vol. XX (1951).
10. Jönsson, G., Brodén, B. and Karnell, J.: Selective angiocardiography. Acta radiol. 32 (1949), 486.
11. Neuhoff, A. and Nabatoff, R.: An angiographic study of the form and function of the remaining lung after pneumonectomy. J. Thoracic. Surg. 20 (1950), 62.
12. Pacheco, C. R. and Del Castillo, H.: Angiographic studies after pulmonary resection. J. Thoracic. Surg. 23 (1952), 262.
13. Rímini, R., Rodríguez, A., Burgos, R., Duomarco, J., Sapriza, J. and Surraco, H. G.: Contribution of angiopneumography to some problems of pulmonary physiopathology. Dis. of Chest. 22 (1952), 539.
14. Steinberg, I. and Robb, G. P.: A visualization study on fibrothorax: Identification of the cardiovascular structures. Radiology 33 (1939), 291.
15. Steinberg, I.: Angiocardiography in pulmonary disease. Am. J. Surg. 89 (1955), 215.

FROM THE ONTARIO CANCER FOUNDATION, LONDON CLINIC (DIRECTOR: IVAN H. SMITH), LONDON, CANADA

ROTATION THERAPY WITH A COBALT 60 UNIT

I. PHYSICAL ASPECTS OF CIRCUMAXIAL ROTATION

by

Paul M. Pfalzner and *W. R. Inch*

The logical extension of the cross-fire technique in radiotherapy is rotational treatment. The advantages of multiple beam cross-firing are universally acknowledged, whereas rotation therapy, in spite of its long history (30, 34) has until recently been regarded with reservations by many. One of the deterring factors in rotation therapy has been the fairly elaborate equipment required and the greater attention to detail necessary for carrying it out. Many of the technical problems are well on the way to being solved, and it is also being realized that methods of treatment which require greater care and accuracy will give better overall results quite apart from improvements due to better treatment technique itself.

The theoretical and practical advantages of rotation therapy with conventional roentgen rays, as well as techniques, measurements and calculations have been reported and discussed in the literature at some length (1, 4, 12, 13, 14, 15, 18, 23, 24, 25, 28, 30, 32, 34, 35), and the supporting evidence of clinical observations, especially in a series of excellent papers by JENS NIELSEN, HOWARD NIELSEN, and co-workers, in Denmark, GYNNING in Sweden, and MALLET in France, has been forthcoming (5, 7, 9, 10, 19, 21, 26, 27, 28, 31, 33). While it is true that, with low half-value layer radiations, rotation therapy results in greater relative improvements in dose distributions over those attainable with stationary fields (1, 14, 15, 23, 25, 28, 33, 34), it is at high energies of radiation that the greatest absolute advantages are obtained (2, 3, 11, 17, 20, 35, 36). It is the decrease in side scatter rather than the increase

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in depth dose which largely determines this improvement, and hence rotational dose distributions change rather slowly over the range of H. V. L. of 0.5 mm Cu to 3 or 4 mm Cu. It can be shown that high ratios of central dose to surface dose are attainable, in the first place, with radiations of an energy such that there is no appreciable side scatter and little absorption within the irradiated volume when using stationary fields, and that still higher ratios will be obtained at energies of over 15 or 20 MeV when the maximum depth dose for stationary fields occurs at or near the centre of rotation. Practical considerations at present make it unlikely that rotation therapy at energies of several tens of MeV will become widely used, especially since cobalt 60 radiation, which has very little side scatter but gives rise to a maximum dose only about 5 mm below the surface, already permits the attainment of highly favourable rotational dose distributions (2, 3, 17). In addition, because at this energy there is a great reduction in differential absorption between bone, fat and soft tissue, phantom measurements in tissue-equivalent unit density material can be regarded with some confidence; this does not apply to lung tissue, however, as a method developed by one of us, based on measured transit dose rates in the thorax, indicates that corrections of from 10 % to 30 % are necessary.

With a stationary teletherapy unit and rotating platform, at least two types of rotational treatment are possible, namely, (a) the patient sitting erect and the beam of radiation directed horizontally, and (b) the patient lying on a stretcher, the beam pointing at an angle of from 40° to 50° to the horizontal. In both cases, the patient is rotated about a vertical axis, the treatment volume usually being made to lie at the intersection of this axis with the beam of radiation. It has recently been suggested by Ellis and Oliver (6) that rotation of type (a) be called "circumaxial", and type (b) "paraxial conical".

This paper describes apparatus and techniques which were developed for carrying out rotation therapy with the stationary Eldorado Cobalt 60 Beam Therapy Unit (8), and will be confined to a discussion of "circumaxial" rotation. Some of the data on dose distributions, though, are also directly applicable to the rotating Cobalt 60 Theratron Units (2, 3), differences arising mainly from the difference in penumbra of the two units. The Eldorado Model at the London, Ontario, Clinic has a source of 2.5 cm diameter, and the geometrical penumbra at a distance of 95 cm, the nearest practical treatment distance for circumaxial rotation is 1.7 cm. The source in the Theratron Model at the Windsor, Ontario, Clinic is also 2.5 cm in diameter, resulting in a penumbra of 4.4 cm at the fixed centre of rotation at 75 cm from the source.

Measurements of dose distributions for "circumaxial" rotation treatment. Calculation of complete dose distributions in rotation is at best tedious,

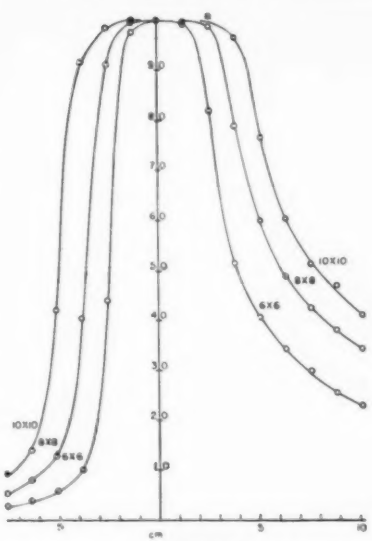

Diagram 1

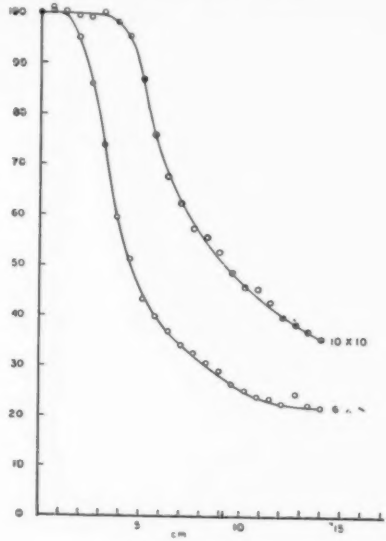

Diagram 2

Diagram 1. Dose distributions in 360° circumaxial rotation, measured in a water phantom, diam. 26 cm. Field sizes given in cm at the axis of rotation, 95 cm from the cobalt 60 source. On the left, vertical sections along the axis of rotation normal to the axis of the beam of radiation; on the right, horizontal sections containing the beam axis.

Diagram 2. Dose distributions in 360° circumaxial rotation, as in the right half of Diagram 1 but diameter of water phantom 42 cm.

and because the radiation distribution at the edge of the beam exerts a decided influence, rarely wholly reliable. It was therefore felt necessary to take direct measurements, using water phantoms. These were cylindrical vessels made of plexiglass; central partitions placed along a diameter of the cylinders allowed insertion of a plexiglass block, of dimensions 24.5 × 24.5 × 2 cm. In the block 304 cylindrical holes (diam. 1.0 cm, depth 1.3 cm) were drilled, regularly spaced in rows and columns 1.27 cm apart. Baldwin Farmer B. D. 2 ionization chambers were inserted into these holes in any required pattern and all unused holes filled with plastic inserts.

Diagrams 1 and 2 show typical dose distributions for 360° rotation, the axis of the phantom coinciding with the axis of rotation. The field size is given at the centre of rotation, 95 cm from the cobalt source. As can be seen the dose falls off rapidly from the central maximum, the relative fall being greater for small fields; the curve of the dose distributions is practically identical for the two sizes of phantoms, the dose

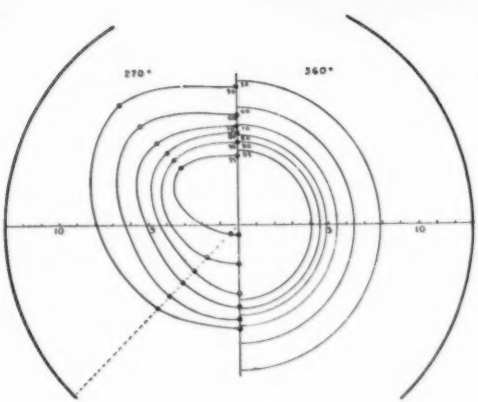

Diagram 3

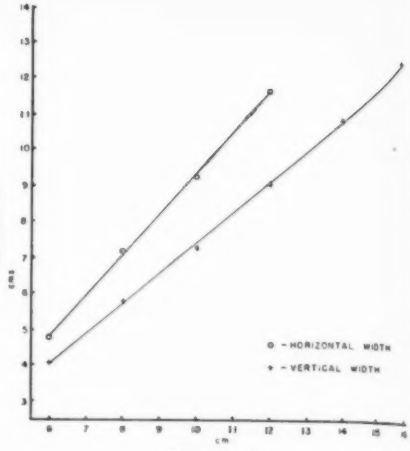

Diagram 4

Diagram 3. Isodose curves in 270° rotation at left, 360° rotation at right. Horizontal section along beam axis. Phantom diameter 26 cm. Field size 10 × 10 cm at the axis of rotation.

Diagram 4. Variation of field width at 90 % level (ordinate) with nominal field width at centre of rotation (abscissa).

falling, of course, to a lower absolute value at the surface of the thicker phantoms. The effect of rotation through less than 360°, for example treatment of a sector of 270°, is shown in the left half of Diagram 3. The horizontal sections show that the maximum dose is shifted away from the centre of rotation along the bisector of the 270° arc.

From dose distributions similar to those of Diagrams 1 and 2, graphs were obtained showing how the width of the central maximum in both the horizontal and vertical direction changes with field size. The width of the central maximum was taken at a level where the dose had fallen to 90 % of its maximum value. The straight line graphs, Diagram 4, show the well known fact that in a combination of co-planar fields, it is necessary to make the field dimension at right angles to the plane of the fields larger than that parallel to this plane for any given size of irradiated volume. It was found that for the same field size at the centre of rotation, an increase in the diameter of the phantoms from 26 cm to 42 cm did not affect the width and shape of the central maximum.

It is recognized that measurements in phantoms often have only limited application to clinical conditions. In this instance, one practical objection which may be raised concerns the effect of the actual shape of human cross-sections as compared to circular outlines. From the experimental results, though, it is seen that variations in diameter do

not significantly influence the size and shape of the central dose maximum, and hence it may be concluded that deviations from a circle can easily be tolerated in the calculation of average central tumour doses. Secondly, the question of the eccentricity of the tumour centre within the contour can also be referred back to the same considerations in all but very extreme cases. A third and more important difficulty concerns the variations in density throughout the human body; this will have its most serious consequences in irradiation of the thorax. The problem is fully dealt with in Part II.

Determining the treatment factors. After the position of the tumour has been localized radiographically or otherwise, the following procedures are carried out:

1) An outline of the patient's body at the tumour level is drawn on paper and the tumour centre, its size, etc., are marked on it.

2) The vertical and horizontal extent of the tumour volume are determined and the required field settings read from the graph (Diagram 4).

3) The method described by JOHNS et coll. (16) is used for determining the ratio of tumour dose to air dose at the centre of rotation. For other points the electronic integrator or graphical method of MOOS and WEBSTER (22) is satisfactory.

4) Using the results of step 3, the daily air dose necessary to reach the tumour dose in the prescribed time is calculated, and the time required to deliver this dose is read from the slide-rule nomogram for cobalt 60 (29).

5) An additional scale inserted alongside the treatment-time scale of the nomogram is used to obtain the speed of rotation of the turntable which will result in an integral number of revolutions during the exposure.

This completes all the necessary steps in preparation of the actual treatment. Slight variations will be needed when rotation over less than 360° is to be given.

Constructional details of the rotation equipment. The rotating component (Figs 1 and 2) consists basically of a steel platform fabricated into a circle of diameter 158 cm. This is supported at its circumference by four grooved idling wheels, and centrally by a thrust bearing. The idling wheels and bearing race are fixed to a fabricated steel base frame. This frame is in turn mounted on fixed hard rubber castors permitting motion along the axis of the treatment beam. The variable speed rotation drive motor is located on the base frame to one side and is coupled to the platform through a conventional worm and toothed gear. The system is designed to give a range of speeds from 0.1 to 0.8 r. p. m.

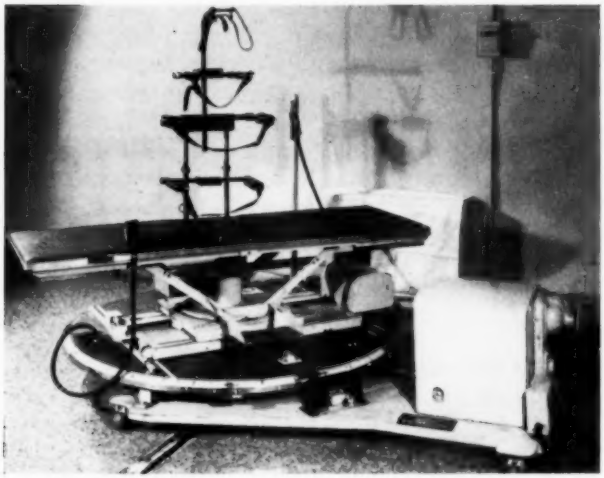

Fig. 1. View of rotation equipment. Centre rear, hand control for motion along floor rail; hand control for cross-movements lies on stretcher top; at far right, handle for adjusting speed of rotation; two cables at right foreground supply power to variable speed motor and to two motors for cross movements. Note adjustable straps and clamps of removable back, head and arm rests, foot rest, and reversing switches under protecting cover, centre foreground, activated by movable trip levers fastened to rim of platform circumference.

The direction of rotation can be reversed automatically by means of reversing contactors attached to the circumference of the steel platform. In this way, treatment over any desired arc of a circle can be given. Push button stations for controlling the rotation manually are located both inside and outside the treatment room.

A three conductor slip ring at the centre of the platform transmits 110 volt power to two electric motors which, by means of two mutually perpendicular worm gears, drive two small square platforms in parallel planes, one above the other. The lower platform is constrained by steel guides fastened to the large circular platform and the upper one by similar guides located on the lower one. The total movement in both cross motions is 25 cm on either side of the centre of rotation and can be traversed in 45 seconds. Operation of the positioning motors is by means of a push button station at the end of a short cable.

A solid steel cylinder of 10 cm outside diameter is mounted vertically and centrally on the upper of the two square platforms in order to receive the stretcher and its supporting frame. This construction allows rotation of the stretcher with respect to the cross movements

and circular platform through an arc of 110°. A locking clamp eliminates this motion when it is not desired. The stretcher top is constructed of plywood padded thinly with sponge rubber and covered with a waterproof material; its overall dimensions are 60 cm by 182 cm.

The patient is supported in a sitting position by a system of adjustable padded clamps and straps which are fastened solidly to the stretcher top. These supports are located at three levels, namely, hip, chest and head, and are easily adjustable for intermediate positions. The patient's arms are supported above his head by means of straps held by an upward extension from the head clamps. The hip and head clamps are removable separately and, when not in use, the entire supporting system can be removed, leaving a flat stretcher surface for treating patients in the supine position.

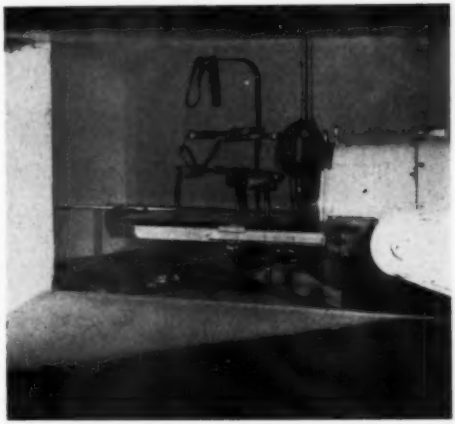

Fig. 2. Rotation equipment, including front and back pointers, as seen through observation window of cobalt treatment room. Head of cobalt unit at right, back-pointer attached to head with special clamp, front pointer slides along horizontal arm graduated in cm.

The entire rotation equipment has overall dimensions of 2.4 by 1.8 metres. However, the minimum space required for operation is a circular area of about 2.9 metres in diameter. The weight of the unit with patient is about 600 kg.

The rotating apparatus is designed so that it can be used in most fixed beam treatments. However, when its use is considered inadvisable (for instance, when the patient's condition is such as to make his transfer to the unit undesirable), provision has to be made for its rapid removal. This is accomplished by a track 4 metres long set flush into the floor in front of the therapy unit and parallel to the treatment beam. (See Fig. 1, bottom left.) A motorized chain and sprocket mechanism which is constrained by this track is connected to the base frame of the rotation unit at two points. This system is operated by a push button station at the end of a cable and allows the apparatus to be rolled away from the cobalt unit so that a conventional stretcher can be admitted. A metric scale is engraved along the side of the track and a pointer attached to the rotation apparatus allows the centre of rotation to be re-set at any desired distance from the source of radiation.

Fig. 3. Chest radiograph taken with Co^{60} radiation. Horizontal shadow extending over right half of chest is due to front pointer. Heavy dot is shadow of lead marker placed over posterior skin mark at tip of back pointer, faint dot just below and to right of it is due to tip of front pointer in contact with anterior skin mark.

Setting-up procedure. The following is a step-by-step outline of the setting-up of a patient for circumaxial rotation treatment.

1) The patient, while sitting in the treatment position, is marked both front and back along a horizontal straight line through the centre of the tumour.

2) The distance between these skin marks is measured and the depth of the tumour determined from radiographs or by examination.

3) The rotation platform is moved along the floor rail until the scale marker indicates that the axis of rotation is at a distance of 95 cm from the cobalt source.

4) The cobalt beam is set horizontally with the aid of spirit levels attached to the head of the therapy unit.

5) The patient is seated in the chair and held in place by adjustment of the hip, back, head and arm rests.

6) The back pointer and front pointer (Fig. 2) are attached to the cobalt head. When the pointers are at their zero positions, the tips meet

at a point lying in the axis of rotation. The pointers are withdrawn a distance equal to the depth of the tumour below the front and back marks, respectively, on the patient.

7) If necessary, the stretcher-chair is rotated relative to the cross-movements until the marks on the patient are parallel to the cobalt beam, *i. e.* to the front and back pointers.

8) The chair is then manoeuvred along its cross movements until the tips of the pointers touch the patient's skin marks. The tumour is now at the intersection of the axis of rotation and the cobalt beam. This can be checked by taking radiographs using cobalt radiation with the rotation platform in two positions differing from each other by from 60° to 120° (see Fig. 3).

Average ratios of tumour dose to air dose are found to lie between 0.65 and 0.80, depending on the size of the treated region. The air dose rate at 95 cm from the source for a 10 × 10 cm field is 25 r/min (June 1955), and hence to deliver 200 r tumour dose requires an exposure time of about 10 to 13 minutes. This is tolerated by patients without any discomfort.

The total time for setting up a patient is of the order of 4 to 7 minutes; thus there results a gain in time and effort because only one setting-up per day is necessary as against from two to six for multiple field beam-directed treatments. Furthermore, a more homogeneous treatment with a lower dose to intervening healthy tissue is achieved.

Acknowledgment

The assistance of a grant from the Ontario Cancer Treatment and Research Foundation for the purpose of establishing techniques and constructing apparatus suitable for rotation therapy with the Eldorado Beam Therapy Unit is gratefully acknowledged.

Much of the early design work and some measurements of dose distributions were made by the late JOHN G. BROWN.

Dr. IVAN H. SMITH's constant encouragement and valuable interest have been essential factors in bringing this project to completion.

The rotation platform was built by the Doyle Equipment Company, whose manager, Mr. FRANK P. GODDARD, co-operated most helpfully.

SUMMARY

Dose distributions as measured in circumaxial rotation with a cobalt 60 teletherapy unit and their variation with axial field size and phantom diameter are presented. A comparison of 360° and 270° rotational isodose distributions is shown. A brief outline is given of the method used to determine rotational treatment factors, and a simple setting-up procedure, using only a front and back pointer and two skin marks, is described. Radiographic positioning checks can be performed satisfactorily for most sites with cobalt 60 radiation. A versatile rotation stretcher-chair combination is described. The treatment is technically convenient and rapid.

ZUSAMMENFASSUNG

Die bei der Rotationsbestrahlung mit einer Co^{60} Teletherapiemaschine gemessene Dosisverteilung und deren Abhängigkeit von der axialen Feldgrösse und dem Durchmesser des Phantomes werden vorgelegt. Die Dosisverteilung bei Rotationsbestrahlung mit 360° und 270° wird gezeigt. Es wird kurz über die Methode, welche zur Bestimmung der Behandlungsfaktoren bei der Rotation benutzt wird, berichtet. Eine einfache Einstellungsprozedur mit nur einem vorderen und hinteren Zeiger und 2 Hautmarkierungen wird beschrieben. Röntgenologische Einstellungskontrollen können für die meisten Situationen mit der Co^{60}-Strahlung zufriedenstellend durchgeführt werden. Eine leicht drehbare und mit guten Fixationsanordnungen versehene Rotationsstuhlkombination wird beschrieben. Die Behandlung geschieht technisch bequem und schnell.

RÉSUMÉ

Les auteurs donnent les distributions de doses mesurées en rotation autour de l'axe avec un appareil de télécobalt-thérapie et leur variation en fonction des dimensions du champ axial et du diamètre du fantôme. Ils comparent les distributions d'isodoses pour des rotations de 360° et de 270°. Ils donnent un bref aperçu de la méthode utilisée pour déterminer les facteurs du traitement rotatoire et décrivent une technique simple de mise en place ne nécessitant qu'un centreur antérieur et un postérieur et deux marques sur la peau. Le rayonnement du cobalt 60 permet pour la plupart des positions un contrôle radiographique satisfaisant de la mise en place. Le traitement est techniquement facile et rapide.

BIBLIOGRAPHY

1. Benner, S., Dahl, O., Hultberg, S., Thoraeus, R., and Vikterlöf, K.: Equipment and technique in precision rotation roentgen therapy. Acta radiol. 43 (1955), 65.
2. Braestrup, C. B., Green, D. T., and Snarr, J. L.: Convergent beam irradiator. Radiology 61 (1953), 614.
3. Braestrup, C. B., and Mooney, R. T.: Physical aspects of rotating tele-cobalt equipment. Radiology 64 (1955), 17.
4. Bush, F.: Rotational roentgen therapy in the horizontal plane. Part III — Theoretical considerations. Acta radiol. 31 (1949), 308.
5. Edling, L.: Experiences with roentgen rotation therapy. Acta radiol. 25 (1944), 427.
6. Ellis, F., and Oliver, R.: On the specification of moving beam therapy techniques. Brit. J. Radiol. 28 (1955), 226.
7. Green, A.: Rotational roentgen therapy in the horizontal plane. Part I — Clinical observations. Acta radiol. 31 (1949), 273.
8. Green, D. T., and Errington, R. F.: 1000 curie cobalt units for radiation therapy. III — Design of a cobalt 60 beam therapy unit. Brit. J. Radiol. 25 (1952), 309.
9. Gynning, I.: Roentgen therapy in cancer of the esophagus. Acta radiol. 35 (1951), 428.
10. — Roentgen rotation therapy in cancer of the hypopharynx. Acta radiol. 35 (1951), 443.
11. Hare, H. F., Lippincott, S. W., Sawyer, D., Trump, J. G., Webster, E. W., Wright, K. A., Evans, W. W., and Granke, R. C.: Physical and clinical aspects of supervoltage rotational therapy. Radiology 57 (1951), 157.
12. Hawley, S. J.: Rotation therapy. Radiology 35 (1940), 65.

13. Jennings, W. A.: Rotational roentgen therapy in the horizontal plane. Part II — Practical application of the method from the physics standpoint. Acta radiol. 31 (1949), 286.
14. Jensen, A.: Dosis measurement in roentgen irradiation of the female pelvis. Acta radiol. 26 (1945), 99.
15. Jensen, H., Nielsen, J., and Thayssen, V.: Evaluation of different factors in rotation therapy. Acta radiol. 25 (1944) 95.
16. Johns, H. E., Whitmore, G. F., Watson, T. A., and Umberg, F. H.: A system of dosimetry for rotation therapy with typical rotation distributions. J. Canad. Ass. of Radiol. 4 (1953), 1.
17. Johns, H. E., Morrison, M. T., and Watson, R. A.: Radiation distributions from a 1000 curie cobalt unit using conventional and rotation techniques. Acta radiol. Suppl. 116 (1954), 550.
18. Kligerman, M. M., Rosen, E. G., and Quimby, E. H.: Rotation therapy technics applicable to standard deep X-ray therapy machines. Radiology 62 (1954), 183.
19. Krebs, C., Nielsen, H., and Andersen, P. E.: Rotation treatment of cancer of the esophagus. Acta radiol. 32 (1949), 305.
20. Laughlin, J. S., Haas, L., Lindsay, J. E., and Beatty, J. W.: Physical aspects of rotation therapy with the betatron. Am. J. Roentgenol. 65 (1951), 947.
21. Mallet, L., and Decker, R.: La cyclothérapie des cancers de l'oesophage. Bull. Assoc. franç. p. l'étude du cancer 38 (1951), 308.
22. Moos, W. S., and Webster, E. W.: An automatic tissue dose computer for use in supervoltage rotational therapy. Radiology 59 (1952), 729.
23. Nakaidzumi, M., and Miyakawa, T.: Über die räumliche Dosisverteilung der Röntgenstrahlen bei der Rotationsbestrahlung. Strahlenther. 66 (1939), 583.
24. Nielsen, H.: Determination of the dose in circular phantoms under rotatory irradiation. Acta radiol. 25 (1944), 183.
25. — Rotatory irradiation. Acta radiol. 37 (1952), 318.
26. Nielsen, J.: Clinical results with rotation therapy in cancer of the esophagus. Acta radiol. 26 (1945), 361.
27. — Indications for rotation therapy. Acta radiol. Suppl. 116 (1954), 541.
28. Nielsen, J., and Jensen, H.: Some experimental and clinical lights on the rotation therapy, its basis and possibilities. Acta radiol. 23 (1942), 51.
29. Pfalzner, P.: Slide rule nomograms for cobalt 60. Brit. J. Radiol. 28 (1955), 170.
30. de Rochemont, R. du M.: Die Dosierungsgrundlagen der Rotationsbestrahlung. Strahlenther, 60 (1937), 648.
31. Simon, S., Henry, J., and Johner, W.: La cyclothérapie des cancers de l'esophage au centre anticancéreux de l'Université de Bruxelles. Bull. Assoc. franç. p. l'étude du cancer 38 (1951) 302.
32. Steed, P. R., O'Connor, A. D., Lamerton, L. F., Winternitz, J. G., Mayneord, W. V., and Smithers, D. W.: Symposium on small field X-ray therapy for deep seated tumours, with special reference to rotation techniques. Brit. J. Radiol. 22 (1949), 185.
33. Thoms, J., Madsen, C. B., and Nielsen, H.: Rotatory irradiation at 400 kV. Acta radiol. 40 (1953), 408.
34. Wachsmann, F., and Barth, G.: Die Bewegungsbestrahlung. G. Thieme, Stuttgart 1953.
35. — Various forms of moving field therapy and its possibilities. Acta radiol. Suppl. 116 (1954), 524.
36. Wheatley, B. M., Steed, P. R., Savage, E. W., King, J. H., Forster, E. W., Hodt, H. J., Jones, I. R., and Smithers, D. W.: The 2 MeV van de Graaff generator installation designed for rotation therapy at the Royal Cancer Hospital. Brit. J. Radiol. 26 (1953), 57.

FROM THE ONTARIO CANCER FOUNDATION, LONDON CLINIC (DIRECTOR: IVAN H. SMITH), LONDON, CANADA

ROTATION THERAPY WITH A COBALT 60 UNIT

II. TRANSIT DOSE MEASUREMENTS AS A MEANS OF CORRECTING TUMOUR DOSE FOR NON-WATEREQUIVALENT ABSORBING MEDIA

by

Paul M. Pfalzner

Published depth dose values and isodose charts are not strictly applicable, as is well known, in the irradiation of inhomogeneous or non-waterequivalent human tissues. In particular, where bone and fat are included in the radiation field, large discrepancies may occur, especially at low quantum energies. Few attempts have been made to deal with the complexities arising in the treatment of, say, the thoracic cavity where the low absorption in lung tissues makes a method of correction quite imperative (4, 7, 9, 10, 11).

One of the advantages of high energy radiations is the fact that absorption in various tissues more nearly equals that in water. However, even with monochromatic radiation of more than 1 MeV, the absorption in the tenuous lung tissues is considerably less than it is in soft tissue or bone or fat, as can be appreciated by a glance at a chest radiograph taken with cobalt 60 gamma radiation (see Fig. 3 in Part I).

If the absorption coefficient of lung tissue were known with any accuracy, it might be possible to apply corrections for the low absorption (10), but in that case the exact thickness of all the tissues in the radiation field would have to be known, or, at least, estimated with some degree of accuracy. It has, however, been shown by NAHON (6) that there are wide variations in absorption in the chest for the same thickness of patient, indicating both different amounts of fat and different

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sizes of thorax but also different absorbing powers from person to person. This fact, then, indicates that only individual measurements in each case will yield reasonably accurate results.

The method adopted by us and to be described here offers the possibility of correcting for these varying factors with an expected accuracy of better than $6^1/_2$ %. Since the corrections to the tumour dose in the thorax found by this method range from about 14 % to over 30 %, this is a tolerable margin of error.

Method

Our techniques employed in circumaxial rotation therapy with a cobalt unit are described in Part I (8). The essential fact is that the patients are sitting in a special chair, and are rotated about a vertical axis. During the treatment, the transit dose is measured with a Victoreen dose rate meter, the chamber being placed at least 70 cm from the patient in the central axis of the cobalt beam. At that distance, the scatter contribution has been found experimentally to be negligible. The rate meter is connected by a long cable to the chamber and the readings are taken outside the treatment room. The transmitted dose rate, I_i, is recorded for every 10 degrees in a 360° rotation, as well as a free air reading, I_o, under the same conditions.

We then have
$$I_i = I_o e^{-\mu_o d_i}, \tag{1}$$

where μ_o = apparent linear absorption coefficient of water for cobalt radiation,

d_i = thickness of water to give an absorption equal to that of the patient.

Using equation (1), d_i values are calculated from the observed values of I_i/I_o and an experimentally determined value of μ_o. From these 36 values of d_i, the corresponding radial distances, R_i, from the centre of rotation to the surface of the effective absorber, are found from

$$R_i = \frac{d_i}{d_{im}} R_{im} \tag{2}$$

or, substituting for d_i from (1),

$$R_i = -\frac{R_{im}}{\mu_o d_{im}} \ln \frac{I_i}{I_o}, \tag{3}$$

where R_{im} = radial distance as measured on the actual body outline of the patient,

d_{im} = corresponding thickness of patient.

The tumour-air ratios corresponding to the R_i values are then determined (JOHNS et coll. 3) and averaged, and the tumour dose calculated.

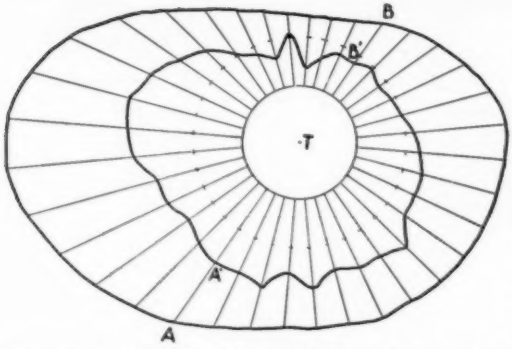

Diagram 1. Outline of a patient's chest showing "effective waterequivalent contour" (inner irregular curve); centre of rotation at T; inner circle represents 90 % isodose level (schematically), and broken circle 50 % isodose level.

The method may briefly be justified as follows:

Since depth dose values are generally determined in water, the most direct way of correcting for non-water-equivalent absorption in human tissues is to reduce the patient thickness to an effective water thickness. Thus the values of d_i denote the thickness of water giving the same relative absorption as the tissues traversed by the beam of radiation.

Having obtained values for d_i, the question arises as to the correctness of the assumptions implicit in equation (2) above. It will be shown that, in practice, an error of less than 3 % is introduced by using this expression. Let us examine one particular thickness, AB, and, for simplicity, postulate that two different absorbers only are encountered in the path of radiation. Again, simplifying, let the central portion be occupied by an absorber μ, and the outer parts on each side by equal thicknesses of an absorber μ_0, where $\mu < \mu_0 =$ apparent linear absorption coefficient of water. This may represent a schematic section through the thorax, where μ is the absorption coefficient of lung tissue and μ_0 that of fat, soft tissue, bones, etc., nearly equal to that of water for cobalt radiation. Let the centre of rotation, T, be within the absorber μ, some distance towards B, say, away from O, the midpoint of AB. (See also Diagram 1.) It can easily be shown that, in order to find the endpoints, A′ and B′, of the effective thickness, d, values of d/2 must be measured not from O or from T, but from an intermediate point O′ such that

$$\mathrm{TO}' = \frac{\mu}{\mu_0}\,\mathrm{TO}. \tag{4}$$

In practice, though, the above simplifications will not hold, and therefore the distance TO′ will not be known. It is then a question as to what error arises when the distances R are measured from T, instead of from O′,

and

$$\begin{aligned} \mathrm{R}_1 &= \mathrm{d}\,\frac{\mathrm{AT}}{\mathrm{AB}}, \\ \mathrm{R}_2 &= \mathrm{d}\,\frac{\mathrm{TB}}{\mathrm{AB}}. \end{aligned} \tag{5}$$

As this involves an unknown error in both R_1 and R_2, although their sum $R_1 + R_2$ is known, it will be instructive to consider Table I below, where it is shown that the resultant error in the sum of the tumour-air ratios, $\Sigma^{D}T/^{D}A$, will, in general, not be greater than 3 % for $d \leq 20$ cm. For $d > 20$ cm, the error may, with increasing eccentricity of T, reach values of 6 to 8 %; such large values, however, will occur rarely only, since the patient's measurements, even if greater than 20 cm in actual diameter, will, in general, be reduced by a large factor in order to arrive at the corresponding effective value of *d*.

Table I

Let $d = R_1 + R_2 = 20$ *cm. Field size:* 10×10 *cm. Cobalt 60 radiation*

R_1 cm	$^{D}T/^{D}A_1$	R_2 cm	$^{D}T/^{D}A_2$	$\sum_1^2 {}^{D}T/^{D}A$	Δ	%
10	0.721	10	0.721	1.442	0	0
8	0.802	12	0.647	1.449	0.007	0.5
6	0.881	14	0.580	1.461	0.019	1.3
4	0.956	16	0.520	1.476	0.034	2.4
2	1.02	18	0.466	1.486	0.044	3.0

R_1, eq. (3), can be determined with an experimental accuracy of about 6 % resulting in an error of only about $3^1/_2$ % in the corresponding $^{D}T/^{D}A$ values. The error in the average value of $^{D}T/^{D}A$ used to calculate the tumour dose will thus be less than $6^1/_2$ %. It has been found experimentally that tumour doses calculated from average $^{D}T/^{D}A$ values, for cobalt radiation at least, give excellent agreement with measured dose values.

Experimental Results

In 360° rotation of the thoracic cavity, transit dose measurements have been made on all patients, and it has been found that the average tumour-air ratios as obtained from the patients' body outlines must be increased by from 14 % to over 30 %. The effective outlines become almost circular, showing the largest shrinkage, as is to be expected, along those directions in which a great deal of lung space is traversed. (Diagram 1.)

Similar measurements in rotation of brain cases resulted in calculated corrections of less than 3 %, *i. e.* within the experimental errors, confirming that the brain is a water-equivalent absorber (2).

Discussion

Our method provides a ready and reasonably rapid means, requiring few special instruments, of correcting for differences of absorption

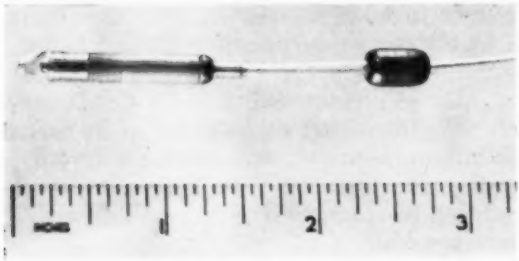

Fig. 1. The Baldwin-Farmer intracavitary ionisation chamber attached to an esophageal probe.

in non-waterequivalent tissues. It is well suited to cobalt 60 circumaxial rotation treatments, as with this radiation quality (a) the tumour-air ratios are fairly insensitive to depth, (as can be seen by the fact that an error of 6 % in R causes only a 3½ % error in the $^{D}T/^{D}A$ values), and (b) the sums of the $^{D}T/^{D}A$ values for a given total thickness do not differ from one another by more than 3 % (Table I). This, of course, applies only to complete 360° rotation where each thickness is irradiated twice in opposite senses. The method could be modified for treatments with parallel opposing pairs of radiation fields but not for ordinary fixed field treatments. While the shape of the isodose distribution is also affected by the inhomogeneities of the medium, this will not be a very large factor, at least for reasonably central tumours, at the energy of cobalt radiation.

Weatherwax and Robb (11) found that for single fields at 200 kV the dose was from 50 % to 70 % higher at a depth of 20 cm when passing through an inflated human lung kept in a water phantom, than the dose obtained in water only; and Quimby et coll. (9) substantially confirmed these figures, showing also that at higher energies the corrections for chest fields become smaller, being of the order of 48 % at 200 kV and 21 % at 700 kV at a depth of 12 cm as measured inside a cadaver.

Kornelsen (4) has described a method of corrections for parallel opposed pairs of roentgen ray fields based on exit dose measurements. Neumann and Wachsmann (7), also working with conventional roentgen rays, have adopted a method based on integrated transit dose in rotation therapy, but as Benner et coll. (1) point out, the drastic approximations involved lead to rather unreliable results.

Our method is receiving confirmation by means of small intracavitary ionization chambers, attached to an esophageal probe, which are exposed during the rotation treatment (Fig. 1), similar to those described by Lidén (5) and others.

A further advantage of transit dose measurements is that they can serve as a check on the constancy of setting up of the patient (1). Usually we take at least two complete sets of 36 readings on each patient, and we find that corresponding values of I_i are consistent to an accuracy of one per cent. This indicates that the patient is not grossly moving during

the treatment and that breathing, for instance, has little effect on the transmitted dose.

The question arises as to how the absorbed dose in the tumour is related to the tumour dose. Our method gives no direct information on this but it is believed that the corrections obtained here are a definite step forward in estimating tumour dose, and hence absorbed dose.

Acknowledgement

It is a pleasure to acknowledge the assistance of W. R. Inch, Ph. D., in making transit dose measurements on patients.

SUMMARY

Transit dose measurements in rotation therapy with a cobalt unit are used to calculate effective water-equivalent chest contours. These are made the bases for arriving at a tumour dose in the thorax corrected for low absorption in lung tissue. Approximate analytical and practical justifications of the method are discussed.

ZUSAMMENFASSUNG

Messungen der Durchgangsdosen bei der Rotationsbehandlung mit einer Kobaltmaschine werden dazu benutzt, die effektiven wasserequivalenten Thoraxkonturen zu kalkulieren. Diese werden der Berechnung der für die geringe Absorption im Lungenwebe korrigierten Tumordosis im Thorax zugrunde gelegt. Approximative analytische und praktische Berichtigungen der Methode werden diskutiert.

RÉSUMÉ

L'auteur utilise les mesures de dose de sortie en thérapie rotatoire avec un appareil à cobalt pour calculer le tracé de l'équivalent efficace en eau du thorax. Ce tracé sert de base pour arriver à une dose à la tumeur dans le thorax corrigée pour tenir compte de la faible absorption dans le tissu pulmonaire. L'auteur examine les justifications analytiques approchées et pratiques de cette méthode.

REFERENCES

1. Benner, S., Dahl, O., Hultberg, S., Thoraeus, R., and Vikterlöf, K.: Equipment and technique in precision rotation roentgen therapy. Acta radiol. 43 (1955), 65.
2. Cederlund, J., Lidén, K., and Lindgren, M.: Depth dose measurements in human brain tissue. Acta radiol. 41 (1954), 473.
3. Johns, H. E., Whitmore, G. F., Watson, T. A., and Umberg, F. H.: A system of dosimetry for rotation therapy with typical rotation distributions. J. Can. Ass. Radiologists 4 (1953), 1.
4. Kornelsen, R. O.: Tumour dose in the chest cavity. Brit. J. Radiol. 27 (1954), 289.
5. Lidén, K.: Depth dose measurements in the esophagus in roentgen rotation therapy. Acta radiol. 30 (1948), 64.

6. Nahon, J. R.: Further comparative studies of x-ray transmissions through the abdomen in living subjects. Radiology 64 (1955), 392.
7. Neumann, W., and Wachsmann, F.: Ermittlung der Herddosis bei Rotationsbestrahlung unter Berücksichtigung der Absorptionsunterschiede im Gewebe. Strahlenther. 71 (1942), 438.
8. Pfalzner, P. M., and Inch, W. R.: Rotation radiotherapy with a cobalt 60 unit. I. Physical aspects of circumaxial rotation. Acta radiol. 45 (1956), 51.
9. Quimby, E. H., Copeland, M. M., and Woods, R. C.: The distribution of roentgen rays within the human body. Am. J. Roentgenol. 32 (1934), 534.
10. Spiers, F. W.: Effective atomic number and energy absorption in tissues. Brit. J. Radiol. 19 (1946), 52.
11. Weatherwax, J. L., and Robb, C.: Determination of radiation values in lung tissue with variable qualities of radiation. Radiology 14 (1930), 401.

FROM CHITTARANJAN CANCER HOSPITAL, CALCUTTA, INDIA

THE UPTAKE OF RADIOACTIVE PHOSPHORUS IN NORMAL BREAST AND BREAST TUMORS

by

N. N. Das Gupta, K. L. Bhattacharya, R. Dutt Choudhuri, A. Bose and *P. K. De*

It is well known that in rapidly multiplying cells, the uptake and turn-over of phosphorus is increased (HEVESY 1948, CHAIKOFF and ZILVERSMIT 1948). Radioactive phosphorus (P^{32}) emits beta rays with a maximum range of 8 mm in soft tissues. Hence its concentration in any superficial region of the body can be detected by means of a Geiger-Müller counter placed over the skin surface. Such surface measurements of beta activity have been used for the differential diagnosis of carcinoma of the breast (LOWBEER et coll. 1946, BHATTACHARYA et coll. 1953), for the study of testicular and intraocular tumors (ROSWIT et coll. 1950, KROHMER et coll. 1953) and also for the investigation of the effect of roentgen radiation on breast tumors (ELLIS et coll. 1951). P^{32} has also been applied in surgery for exploring the boundaries of carcinoma of the brain (SELVERSTONE et coll. 1949, STAPLETON et coll. 1952). The value of this method, however, is limited by the low penetrating power of the beta rays on the one hand, and by the fact that benign tumors and inflammatory conditions are also known to cause an increased uptake of phosphorus (LOWBEER 1950).

The present investigation was undertaken to test critically, how far it is possible to differentiate between malignant and benign breast tumors, from the superficial counting rates over the tumors when compared with those obtained over the normal breast; and further to find out if there were any differences in the time-rate of collection or release of radioactive phosphorus in the two types of tumors. In the case of breast tumors removed by surgery, the concentration of radioactivity per g of tumor

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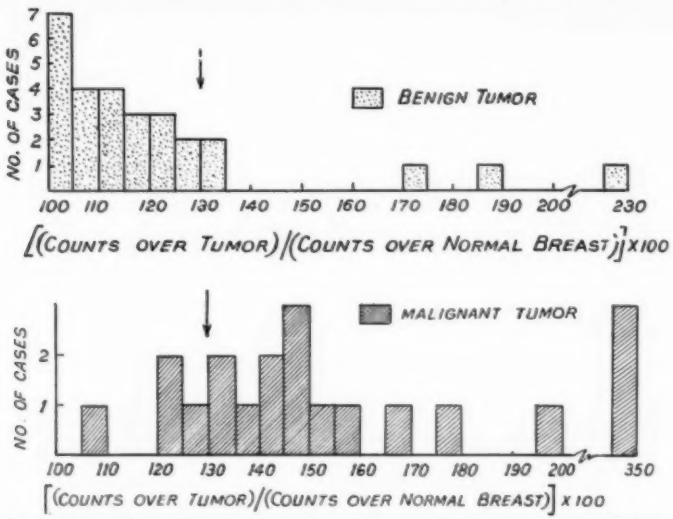
NO. OF CASES
BENIGN TUMOR
100 110 120 130 140 150 160 170 180 190 200 230
[(COUNTS OVER TUMOR)/(COUNTS OVER NORMAL BREAST)] X 100
NO. OF CASES
MALIGNANT TUMOR
100 110 120 130 140 150 160 170 180 190 200 350
[(COUNTS OVER TUMOR)/(COUNTS OVER NORMAL BREAST)] X 100

Diagram 1. Distribution of benign and malignant tumors by superficial percentage counting rate.

and its surrounding normal tissue was measured directly, and some attempts made to correlate the results of such in vitro measurements with the pathologic picture.

Materials and Methods

Only cases of palpable mammary tumors were the subjects for this study. In every case, a single tracer dose of radioactive phosphorus (P^{32}) as $Na_2 HPO_4$ (the material used in these experiments was obtained from the Atomic Energy Research Establishment, Harwell, England) was administered intravenously, the dose being about 0.01 μc per g of body weight of the patient. The beta activities over the skin covering the tumor, as well as over identical sites of the normal breast, were measured with a thin-walled Geiger-Müller counter (wall thickness 35 mg/cm^2). The counter was placed in contact with the skin surface for this purpose.

The measurement of the surface beta activity was repeated at 2, 6, 10, 24, 30, 36, and 48 hours, after the injection. The percentage counting rate over the tumor, defined by (counting rate over the tumor) / (the counting rate over identical sites of the normal breast) $\times$ 100, was determined for each hour and the mean percentage counting rate for the interval 2 to 48 hrs after the injection was deduced for each case. This average surface counting rate was considered to be more significant

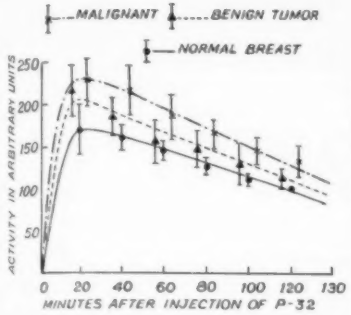

Diagram 2. Variation of surface beta activity over the normal breast, benign, and malignant tumors, 0 to 2 hrs after injection of P^{32}.

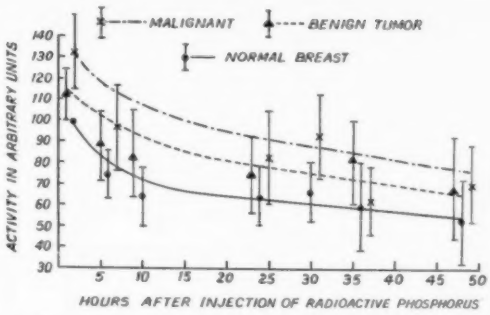

Diagram 3. Variation of surface beta activity over the normal breast, benign, and malignant tumors, within the interval 2 to 48 hrs after injection of P^{32}.

as an indicator of malignancy, or otherwise, than the ratio taken at any fixed hour after the injection.

Forty-eight (48) cases of breast tumors were studied in this series. Except in a few cases, the histologic diagnosis was based either on aspiration biopsy or on examination of surgically removed specimens. The distributions of benign and malignant tumors by superficial percentage counting rate are representated in the histogram (Diagram 1).

The following procedure was adopted in order to obtain the mean *variation of the surface beta activity with time* for all the cases under investigation. In any particular case, the activity over the normal breast two hours after the injection was taken as the reference point and made equal to 100. All other surface measurements for the same case, either over the normal breast or over the tumor, were expressed with reference to this standard. Thus, reduced surface beta activities over the tumor and normal tissues at different hours were then averaged for all cases and standard deviations obtained. This procedure enabled us to take account of any variations in counter efficiencies in the course of measurements lasting over two years, and also of any uncertainty in injection of the radio-isotope in any particular case. The values of the mean surface beta activities (with the standard deviations) at different hours for malignant, benign tumors, and also for normal breast, are given in Table I and plotted in Diagram 3.

In order to obtain the initial part of the uptake curve more accurately, in 25 per cent of the cases the surface beta activity was also measured at intervals of ten minutes within the first four hours after the injection. The results of these measurements on the initial rise of the surface beta activity with time are shown in Diagram 2.

Table I

Variation of the surface counting rate over tumor and normal breast with time. (Counting rate over normal breast two hours after injection made equal to 100)

Time after injection	Percentage Counting Rate over		
	Normal breast	Benign tumor	Malignant tumor
20 min	170 ± 32	216 ± 33	224 ± 28
40 min	160 ± 14	183 ± 21	213 ± 27
60 min	146 ± 12	154 ± 24	188 ± 21
80 min	127 ± 9	147 ± 21	164 ± 17
100 min	111 ± 7	130 ± 23	144 ± 15
2 hr	100	113 ± 12	132 ± 18
6 hr	74 ± 11	88 ± 17	96 ± 20
10 hr	64 ± 15	83 ± 22	74 ± 10
24 hr	63 ± 14	74 ± 18	82 ± 22
30 hr	66 ± 14	61 ± 6	92 ± 20
36 hr	59 ± 22	81 ± 19	62 ± 16
48 hr	52 ± 20	68 ± 20	69 ± 19

Table II

Specific activity per g of tumor and surrounding normal breast tissue, with an injected dose of 0.01 μcs/g of body weight of the patient

Pathology	Specific activity of specimen in μc/g				Activity of tumors as per cent of that of the normal tissue	Percentage count rate over tumor from superficial measurement
	Adjacent Normal Tissue	No. of separate Assays	Tumor Tissue	No. of separate Assays		
Paget's Disease	0.0048	1	0.022	1	460	348
Cystic hyperplasia with infiltrating duct carcinoma	0.003	2	0.015	2	500	125[2]
Medullary carcinoma	0.0059	4	0.057	5	960	350
Infiltrating duct carcinoma	0.009	2	0.021	6	234	180
Intraductal carcinoma	0.0035	4	0.0055	2	160	160
I.D.C.[1] with much cellular stroma	0.0033	3	0.017	3	515	—
Cystic Hyperplasia	0.0073	3	0.023	2	315	187
I.D.C. with productive fibrosis	0.0038	2	0.0058	2	153	141
I.D.C. with pleomorphic cell type, much cellular stroma infiltrated with lymphocytes	0.0104	1	0.103	4	990	—
Intraductal carcinoma	0.0087	3	0.0108	3	124	108[2]
Cystic hyperplasia	0.0012	3	0 0033	3	267	—
I.D.C. comedo type mixed with colloid carcinoma in an adjoining portion, and I.D.C. with productive fibrosis in another portion	0.0024	3	0.025	2	1,040	125[2]

[1] I.D.C. = Infiltrating duct carcinoma. [2] False negative predictions from superficial measurements.

A direct measurement of the *uptake of P^{32} per g of tumor and normal tissue* was possible in a few of the cases which were operated upon. Two days before the operation, intravenous injections of the tracer

dose of radioactive phosphorus (approximately 0.01 μc per g of body weight) were given and the superficial measurements completed within the next 48 hours. The specimens of breast tissue after operation were sliced and separated macroscopically into malignant and non-malignant blocks. From each block the central portion was sent for histologic examination and the surrounding portions assayed for radioactivity. The samples selected for radioactive assay work were weighed and then ashed in a muffle furnace at 600° C. The ash was dissolved in 2N HCl and radioactivity per g of tissue determined. The counts per minute were converted to absolute activity in μc by comparison with a simulated standard P^{32} source. (Simulated P^{32} reference source contained $Uranium^{238}$ in secular equilibrium with $Thorium^{234}$ and $Protoactinium^{234}$. This combination having almost infinite half-life and the same spectral distribution of beta rays as P^{32}, and previously calibrated against a U. S. Bureau of Standards P^{32} solution, served as simulated standard.) The results of these measurements are given in Table II.

Observations

Correlation of the mean percentage counting rate over tumor with the histologic report. Out of the 48 cases studied in this series, 20 were histologically malignant. Seventeen (17) of these 20 malignant tumors (85 %) had a mean count equal to or greater than 130 %, while 3 malignant tumors had counts less than 130 % of that over the normal breast. One malignant case had a count less than 110 %. The three cases with counts higher than 300 % were ulcerated and infected types of breast cancers. Out of the 28 benign tumors, 23 (82 %) had counts less than 130 %, while 5 cases (18 %) gave counts greater than 130 %. A very large fraction of the benign tumors (about 40 %) had ratios within 110 % of the normal.

If, in view of these results, a counting rate over the tumor equal to or greater than 130 % of that over the normal breast, be regarded as suggestive of malignancy, then the diagnosis based on tracer measurements agreed with the histologic finding in 40 out of 48, *i. e.* 83 % of the cases. In 8, or 17 % of the cases, there were failures; the radio-isotope measurements led to a prediction which was at variance with the histologic diagnosis. These failures are discussed in detail later.

The variation of the surface counting rate over tumor and normal breast with time. Table I and Diagrams 2 and 3 present the results of measurements of surface activities at different times after the injection, averaged for all the cases studied. The maximum activity was registered (on the average) within about 20 minutes following the intravenous injection;

after which there was a decline in the surface beta activity (ELLIS et coll. 1951, KROHMER et coll. 1953).

Owing to large variations in the individual counts, the standard deviations in the mean results were large; but, except for two points, smooth curves passing through the limiting errors could be drawn for the normal breast as well as for the benign and the malignant tumors. In order to avoid overlapping of the limiting errors for the different groups, in the representation of the results in Diagrams 2 and 3, each point for the benign and the malignant tumor has been shifted slightly to the left and right respectively with respect to the corresponding points for the normal breast.

From the slopes of the logarithmic plots of the activities shown in Diagrams 2 and 3, it was possible to deduce the effective half-lives with which the surface beta-activities died out. It was found that immediately after reaching the peak, the beta-activity died out with a very short effective half-life of 2 hours. After this initial rapid decay, the activity died out more slowly with an effective half-life of about 72 hours in all the three cases.

These results therefore indicate, (a) that although there are large variations in values measured for individual cases, on the average, the activity at any time over the malignant tumor is higher than that over the benign and that the activity over the benign tumor is higher than that over the normal breast, and (b) that the activities over the malignant or benign tumors die out in almost the same way as that over the normal breast. On account of the large statistical errors in the present data, no appreciable difference in the rate of accumulation or release of radioactive phosphorus by the tumor tissue and the normal breast could be established with certainty.

Activity per g of tumor and normal tissue. Satisfactory specimens for radioactive assay work were obtained only in 12 cases in this series. The results of measurement of P^{32} concentration in weighed samples of the various portions of excised tissue are given in Table II. Column 1 shows the histologic reports on individual cases, while Columns 2 and 4 contain the specific activities per g of normal and tumor tissue, respectively.

These activities are valid for the day of operation, usually two days after injection of the radio-isotope. The number of separate radio-assays, on which these estimates are based, have been indicated in Columns 3 and 5. The activities of the different tumors, as percentages of those of the normal tissue on the date of operation *i. e.* (Column 4 divided by Column 2) $\times$ 100, are given in Column 6. These are the percentages obtained from *in vitro* measurements. The percentage counts over tumor

with respect to those over normal tissue obtained from superficial measurements, have been included in Column 7 for comparison.

Out of the 12 cases studied 10 were definitely malignant. In these 10 cases, the concentration of the radio-isotope per g of normal tissue varied from 0.0024 μc/g to 0.0104 μc/g *i. e.* by a factor of 4.5. The corresponding variation in the activities of the malignant tumor tissues was from 0.0055 μc/g to 0.103 μc/g *i. e.* by a factor of 18.7. Thus so far as variation in the power of concentration of phosphorus is concerned, there was a very marked difference between the malignant cells and the normal. The activities of malignant tissue in different cases varied from 124 % to 1,040 % of the normal, with a mean of 500 %. For the ten malignant tumors listed in Table II, the mean concentrations of radioactive phosphorus per g of malignant and the surrounding normal tissues were as 0.027 and 0.0055 μc/g. Thus on the average, malignant tissues concentrated 5 times as much phosphorus as the surrounding normal structures and therefore received on the average 5 times as much irradiation as the latter. However, as shown in Table II, there were large variations from the mean in individual cases. The mean concentrations per g were 270 % and 55 % of the injected dose of 0.01 μc/g body weight of the patient.

From the results presented in Table II, it appeared that there was some correlation between the degree of differentiation of the tumor and its uptake of radioactive phosphorus (STAPLETON et coll. 1952). The two cases of intraductal carcinoma showed low uptakes of 160 % and 124 % with respect to the normal. This is in agreement with the common idea that the prognosis of this kind of tumor is better than that of infiltrative varieties. Four (4) tumors of the infiltrative type were studied, and showed on the average an uptake of 350 % of the normal tissue. One case of medullary carcinoma and another of infiltrating duct cancer with pleomorphic cell type, which are ordinarily regarded as being more malignant, showed very high uptakes, of 960 % and 990 %, respectively. The last case showed three types of pathologic changes and a very high uptake of radioactive phosphorus; the presence of the colloid type was thought to be favourable in prognosis, but WILLIS (1953) is of the opinion that "they are not of such low malignancy as commonly believed and are no less productive of metastases than other invasive types of growths". The high uptake is in favour of this view.

The two cases of cystic hyperplasia studied in this series showed relative uptakes of 315 % and 267 % compared with normal breast tissue. These relatively high concentrations of phosphorus in such cases which are usually regarded as benign tumors, lend some support to the view held by many pathologists, that these kinds of lesions in the breast in middle-aged women have pre-cancerous possibilities (WILLIS 1953).

It must be remarked, however, that the number of cases in which the activities per g were studied in this series is too few to justify any generalised statements about uptakes in different types of malignant lesions. Further work is needed in order to settle this point which is important for a clear understanding of the differences between different types of neoplasms and of the therapeutic possibilities of the use of radioactive phosphorus.

Discussion

The correlation of the ratios of activities per g of tumor and normal tissue obtained from direct *in vitro* measurements, with those from superficial *in vivo* measurements, is extremely difficult due to the presence of several complicating factors in each case.

Although all possible care was taken in the macroscopic as well as in the microscopic examination of neighbouring tissues to ensure that the blocks selected for radioactive assay work consisted only of normal and tumor tissues respectively, it was practically impossible to be certain that the samples on which radioactive assay work was carried out contained exclusively either malignant or benign tumor or normal tissues and that there was no mixture in any case. Moreover, the tissues selected as normal were those taken from the operated samples and were closely associated with and adjacent to the tumor tissues; there was no knowing how far they differed, as far as phosphorus concentration was concerned, from the absolutely normal tissues of the other breast. Finally, even inside the same tumor mass, large variations in concentration of phosphorus per g were noticeable for the different portions of the excised tumor. Such variations were possibly characteristic of all tumors. The values reported in Table II were only the averages of several separate radio-assays carried out on samples from different parts of the operated specimen. These limitations of the *in vitro* measurements must be considered when comparing them with the results of *in vivo* measurements.

In contrast to the direct *in vitro* measurements, the count registered by a counter placed over the skin surface, after the injection of radioactive phosphorus, is determined by several variable factors such as the counter geometry, its overall efficiency, and the distribution of radioactive material within the tissues underneath. In general, one may say that there is a 'detectable volume' inside the tissues, beta rays from the different parts of which will reach the counter in varying degrees depending on the absorption and scattering in the overlying tissues. If now a tumor of any arbitrary shape and volume is also situated within this detectable volume, and has a uniform concentration of radioactive phosphorus which is n times that of the surrounding tissues, a fraction

of the beta rays emitted from the tumor will be registered by the surface counter along with those from the normal tissues remaining within the detectable volume. It is obvious that the contribution of the tumor in the superficial counting rate, will vary with the size of the tumor relative to the detectable volume, its depth below the skin, situation with respect to the counter axis etc. Moreover, the concentration of phosphorus in the different parts of the tumor may also vary. All these factors will change from case to case and it will be difficult to determine them with sufficient accuracy preoperatively. In view of the presence of so many complicating factors, not even a very rough agreement between the ratios obtained from the *in vivo* and *in vitro* measurements is to be expected.

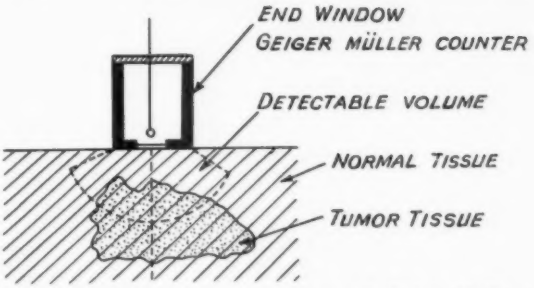

Fig. 1. Schematic representation of Geiger-Müller counter, detectable volume, and tumor and normal tissue.

For nine cases, the ratios of tumor activity with respect to that of the normal tissues are available both from the superficial measurement as well as from *in vitro* measurements. It is found that the ratios from *in vitro* measurement are as 1 to 8 times of those from *in vivo* measurements. This is to be expected. The ratios from the superficial measurements will always be lower than those from the direct measurements of activities per g. The deeper the tumor and the smaller its volume relative to the detectable volume, the fewer will be the beta rays from it which will reach the surface counter and be registered there. In the limiting case the superficial ratio will approach unity even though the actual tumor may have a high concentration of P^{32} per unit mass.

It is thus clear that the limiting ratio of 130 per cent which we have assumed as the line of division between the malignant and the benign tumors, is not a very critical one. In any series of measurements the limiting ratio will depend on a number of factors, such as the distribution of tumors as regards size, their depth below the skin surface, position within the detectable volume, and the counter geometry used which determines the detectable volume. In spite of the uncertainties introduced by so many varying factors, it is remarkable that the results of the present study show that in a very large number of cases — 83 % in the present series — the predictions of malignancy based on P^{32} measurements agree with the pathologic report. It is also true that not all tumors

can be diagnosed unequivocally before operation, particularly when the aspiration biopsy result is negative. In view of this, it must be concluded that the P^{32} method may be a very useful adjunct to the already existing methods of cancer diagnosis.

Let us now review the likely causes which might have been responsible for the failure of the radioactive method to arrive at the correct diagnosis in the eight cases previously mentioned (see Diagram 1).

There were false negative predictions in three cases. All these cases were definitely malignant (histologic reports for individual cases are listed in Table II), but the surface counting ratios in the three cases were as low as 125 %, 125 % and 108 %. The direct measurement of the concentration of P^{32} per g led to ratios of 500 %, 1,040 % and 124 %, respectively. The great difference between *in vivo* and *in vitro* measurements and the failure of the surface counter to detect the excess concentration of P^{32} inside the tumor even though present, must be ascribed to the fact that the tumors in the first two cases were at depths greater than 5 mm under normal tissues. Most of the beta rays emitted from P^{32} concentrated in the tumors were filtered off by the overlying tissues and failed to reach the counter in the first two cases. In the last case even the *in vitro* measurement indicated a very low concentration. This was an early stage of infiltrating cancer in which the infiltration had just begun and it was difficult to separate the malignant portion exclusively for radioactive assay work. This possibly accounted for the low ratios in the *in vitro* measurements.

There were five cases which were pathologically benign tumors but had superficial counting rates over tumor greater than 130 % of that over the normal breast. One of these, a cystic hyperplasia with a high superficial counting ratio of 187 % over the tumor, has already been referred to and discussed in the previous section.

An interesting case was one of a woman, aged 45, with a hard nodular growth measuring approx. $13 \times 8 \times 5$ cm in the upper medial quadrant of the left breast with enlarged axillary glands. The histologic report on the surgically removed specimen was tuberculous mastitis, but the percentage counting rate over the tumor was unusually high, viz. 230 %. Another case of tuberculous mastitis, not included in this study, also indicated a very high relative uptake of 700 per cent from direct *in vitro* measurement. Thus both these cases indicated a high concentration of P^{32}, although no definite conclusion can be made from only two cases.

Another patient, aged 25, had both breasts affected and the percentage counting rate had to be measured with respect to the thigh — a comparison which might not be quite justified. Aspiration biopsy did not reveal any malignant cells. The observed counting rate over one breast, greater than 130 % of that over the thigh, might have been due to the differences in the geometric conditions.

The tumors in two cases did not reveal any malignant cells on aspiration biopsy, but the percentage counting rates of 135 % and 175 %

respectively, were rather high for benign tumors. However, as the cases were not operated upon and aspiration biopsy results were negative, malignancy could not be absolutely ruled out.

We have considered in detail the eight cases in which the predictions from the radioactive tracer measurements did not agree with the subsequent diagnosis from histologic examination. The following two cases were of particular interest as in both of them, although the aspiration biopsy seemed to indicate malignancy, the counting ratio over the tumor with P^{32}, was within the normal limits, and subsequent examination of the operated specimen confirmed the prediction based on P^{32} measurement.

One patient, aged 20, had a hard tumor measuring $6 \times 5 \times 4$ cm in the upper lateral quadrant of the right breast. On aspiration biopsy, cells highly suspicious of malignancy were found; however, the counting rate over the tumor was only 115 % of that over the normal breast. Examination of tissues after operation revealed the condition as one of fibroadenoma, thus confirming the diagnosis by P^{32}.

Another patient, aged 24, had a hard tumor about $4.5 \times 4.5 \times 4.0$ cm on the left breast for one year. It was first diagnosed as malignant from aspiration biopsy. The superficial counting ratio over the tumor was 120 per cent of the normal, which seemed to indicate the benign nature of the mass. An examination of the surgically removed specimen proved the tumor to be a fibroadenoma, thus confirming the radio-active diagnosis.

Thus it appears that although the method of diagnosis based on superficial measurements with P^{32} is not infallible, it may be a very useful procedure in the diagnosis of carcinoma of the breast and should be undertaken whenever possible.

Acknowledgments

This work was carried out under the auspices of the Atomic Energy Commission of the Government of India. The authors are greatly indebted to Dr. Subodh Mitra, Director of the Chittaranjan Cancer Hospital, for his kind interest in this work, to Mr. K. P. Chakraborty for help in radio-assay work, and to the surgeons Mr. A. K. Sen and Mr. K. P. Das for the supply of breast tumor tissues after operation.

SUMMARY

Radioactive phosphorus (P^{32}) was administered to 48 patients with breast tumors and the superficial beta activity over the tumor and over a corresponding site of normal breast measured. The relative activity in 85 % of the histologically proved malignant tumors was found to range from 130 to 350 % of the normal, while 82 % of the benign tumors showed an uptake ratio ranging from 100 to 130 % of the normal. In about 17 % of the total number of cases, the probable diagnosis based on radioactivity measurement was at variance with the histologic report. It is suggested that the use of P^{32} in the diagnosis of malignancy can be a useful adjunct to the already existing pathologic test.

ZUSAMMENFASSUNG

Bei 48 Patienten mit Brusttumoren denen man P^{32} verabreicht hatte, wurde die oberflächliche Betaaktivität über dem Tumor und über dem entsprechenden Teil der normalen Brust gemessen. Man fand, dass die relative Aktivität in 85 % der histologisch sichergestellten malignen Tumoren zwischen 130 bis 350 % über der Norm lag, während 82 % der benignen Tumoren ein Aufnahmeverhältnis von 100 bis 130 % des Normalen zeigten. In etwa 17 % aller Fälle wich die auf Radioaktivitätsmessungen begründete Wahrscheinlichkeitsdiagnose von dem histologischen Bericht ab. Es wird angedeutet, dass die Benutzung von P^{32} für die Diagnose der Malignität ein wertvoller Zuschuss zu dem schon bestehenden pathologisch-anatomischen Test sein kann.

RÉSUMÉ

L'auteur a administré du phosphore radioactif (P^{32}) à 48 malades atteintes de tumeurs du sein et a mesuré l'activité bêta superficielle au-dessus de la tumeur et au-dessus de la région correspondante du sein normal. Dans 85 % des tumeurs dont la malignité était prouvée histologiquement, l'activité relative fut trouvée comprise entre 130 et 350 % de la normale, alors que 82 % des tumeurs bénignes ont présenté un taux de fixation allant de 100 à 130 % de la normale. Dans environ 17 % du nombre total des cas, le diagnostic probable basé sur la mesure de radioactivité était en contradiction avec le compte-rendu histologique. Les auteurs suggèrent que l'emploi du P^{32} peut s'adjoindre utilement pour le diagnostic de malignité au test anatomo-pathologique déjà existant.

REFERENCES

Bhattacharya, K. L., Dutt Choudhuri, R., Bose, A., and Das Gupta, N. N.: Diagnosis of Breast Cancer with Radioactive Phosphorus P-32. J. Indian. M. A. 22 (1953), 393.

Chaikoff, I. L., and Zilversmit, D. B. *In:* Advances in Biological and Medical Physics. Vol. 1, p. 330. J. H. Lawrence and J. G. Hamilton Ed. Academic Press. New York 1948.

Ellis, F., Hoch-Ligeti, C., and Oliver, R.: Investigation of the effect of X-radiation on the localisation of radioactive phosphorus in Breast Tumours. Brit. J. Cancer 5 (1951), 45.

Hevesy, G.: Radioactive Indicators. Interscience, New York 1948. (References to early work given here, p. 118.)

Krohmer, J. S., Thomas, C. I., Storaasli, J. P., and Freidel, H. L.: Detection of Intraocular Tumors with the use of Radioactive Phosphorus, Radiology 61 (1953), 916.

Lowbeer, B. V. A., Glenn-Bell, H., McCorkle, H. M., and Stone, R. S.: Measurement of Radioactive Phosphorus in Breast Tumors in situ: A Possible Diagnostic Procedure. Radiology 47 (1946), 492.

Lowbeer, B. V. A.: The Clinical Use of Radioactive Isotopes. C. C. Thomas Springfield, Illinois 1950.

Roswit, B., Sorrentino, J., and Yalow, R.: The Use of Radioactive Phosphorus (P^{32}) in the Diagnosis of Testicular Tumors: a Preliminary Report. J. Urol. 63 (1950), 724.

Selverstone, B., Solomon, A. K., and Sweet, W. H.: Location of Brain Tumors by Means of Radioactive Phosphorus. J. A. M. A. 140 (1949), 277.

Stapleton, J. E., McKissock, W., and Farran, H. E.: The Uptake of Radioactive Phosphorus in Normal Brain and Brain Tumors. Brit. J. Radiol. 25 (1952), 69.

Willis, R. A.: Pathology of Tumors. Butterworth, London 1953.

BOOK REVIEWS

ROENTGENOLOGISCHE FUNKTIONSDIAGNOSTIK MITTELS SERIENAUFNAHMEN UND KINEMATOGRAPHIE. Von Robert Janker. 2 Bände. Textteil 110 S., Bildteil 184 S., 191 Abb. Verlag W. Girardet, Wuppertal-Elberfeld 1954. DM. 39: —.

Various methods for serial exposures and cinematography, including simple manually operated film changing devices, as well as more complicated mechanisms for the production of direct exposures on roll film, are first reviewed in detail. Indirect methods for the transfer of a fluoroscopic image, reduced in size by optical means, on to film, as well as the use of image amplifiers are fully dealt with. Mention is also made of the simultaneous recording of cardiac sounds and the employment of ECG.

The methods are compared from different angles. The resolving power is clearly surveyed in tables, and the sensitivity of various photographic materials demonstrated by means of density curves. Observations are made regarding the importance of focus dimension and unsharpness due to motion. Special procedures for printing serial films are also described. Comparisons are made between the different methods with special regard to the relative requirements of tube loading and from the point of view of radiation dosage rates as well as the skin dose per second; these are illustrated by tables. Indications for different examinations are dealt with in a separate section in which the required number of images per second, the duration of the examination, the need for exposure in different planes, as well as the economics of examinations, are discussed. In another section the author gives examples of 'functional' examinations and, in this connection clinical data, the course of the investigation, as well as technical requirements and examination results are described with a wealth of illustrations.

Adequate space is allocated to a discussion of questions related to radiation dosages and protection, questions which so far seem to have been the subject of but little interest. Clarifying data on dosage conditions are presented and the permissible number of exposures is computed for the various investigation methods. The elaborate protection provided for the personnel in the form of cage-like wall systems enclosing the patient, may be noted.

In the reviewer's opinion, it would have been desirable had the higher energy levels, which are now coming more and more into use, been included in the comparative tests of the different methods. The 100 kV range has, for many examinations, already been considerably surpassed. In the discussion on the resolving power of various methods, to which the author reverts in many connections, it would have been useful if it had been pointed out that the resolution, as visually perceived, is more intimately related to contrast, and that fine systems of lines producing maximal contrast do not correspond to ordinary roentgenographic conditions. The extremely accurate data on the resolving power presented in some of the tables, in which even fractions of line/mm are given, occasion some surprise. It ought to have been stressed more clearly that in this connection the conditions of development, contrast of object, etc. must be taken into account.

An exquisite illustrative material aptly chosen for exemplifying the application of the different methods is included. The reproductions are of a quality seldom encountered, the blocks and typographic layout being of the highest standard. It may, of course, be a matter of argument whether it is advisable to arrange the illustrative material in a separate volume. The extensive pictorial series presented in this work — parts of cinematographic and other serials — in many instances fill several book pages for one and the same radiographic study. It seems useful in such cases to have the illustrative material collected in a separate volume, since otherwise the text of the subject matter tends to be broken up too much. The work is a contribution of importance for disseminating information concerning the new methods and their associated problems.

Ove Mattsson.

BRONKUS UND TUBERKULOSE. Bronchoskopische und Bronchographische Untersuchungen der Bronchen bei der Tuberkulose. Von A. Huzly und F. Böhm. 138 S., 258 Abb. Fortschr. Röntgenstr. Erg. Bd. 73. Georg Thieme Verlag, Stuttgart 1955. DM 57: —.

The book deals with bronchial changes in cases of tuberculosis of the pulmonary parenchyma and thoracic lymph glands, and changes occurring in cases of pleural effusion and thickening of the pleura as well as those resulting from active methods of treatment. Bronchial tuberculosis and residual states of cicatrization are treated in special chapters. In the reviewer's opinion, the disposition of the material is to some degree unsatisfactory, since its division follows no uniform principle. The work is based on a series of 3,213 bronchoscopies and 2,373 bronchographies; of these, some 50 cases are discussed and their case histories, bronchoscopic findings, and roentgenograms, presented.

The illustrations comprice a large number of photographs of anatomic preparations, frequently accompanied by descriptive drawings and bronchoscopic appearances, and this picture material is excellent. Unfortunately, the same can only partly be said about the roentgenograms. Only in a few cases is the pathologic anatomy clearly illustrated by the bronchograms. Many of these are unsharp, which in some cases at least must be due to insufficient anaesthetization as evidenced by the contracted bronchi. Too much contrast medium has frequently been used, and in some cases the views have been taken too late so that a considerable amount of the water soluble medium lies in the parenchyma. Films are also included, in which contrast medium is present in the contralateral lung and this has made it impossible to produce true lateral views of the actual lung under examination.

The style is at times too verbose and often lacking in lucidity particularly as regards the roentgenologic material. For example, the expression "Verschattung und fast normales Röntgenbild" is used instead of exact patho-anatomic terms. Terminology, which at least in contemporary Anglo-Saxon literature is generally accepted, has not been employed; the bronchial branches are designated with letters and numbers. One might assume from the work that the author was not completely familiar with all the modern aspects of radiology, for the radiologic part of the book is not equal to the high standard of the remainder. This is to be regretted, since radiologists possess the best opportunities of demonstrating bronchial changes due to tuberculosis.

Uno A. T. Norlin.

RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (Revised December 1, 1954). 92 pages, 11 diagrams, 23 tables. British Journal of Radiology, Suppl. 6. London 1955. Price: 10s. 6d. with paper cover, 12s. 6d. with cloth cover.

The large increase in size of this volume in comparison to its predecessors reflects the increase, due to known causes, of the number of persons exposed to radiation and the increasingly complex and varied nature of radiation risks.

An introduction on the organization of the Commission and its Sub-Committees and a list of members is followed by a glossary of terms with explanations. Besides a maximum permissible dose for professional exposure, a similar limit, ten times lower, for large populations is for the first time introduced into the Recommendations. General principles on radiation protection, health control and monitoring are given.

Sub-Committee I reports on the permissible dose for external radiation to the body as a whole and to different "critical" organs. Relative biological efficiencies are given for different radiations.

The largest single contribution is the one from Sub-Committee II on permissible dose for internal radiation, containing tables on the chemical composition and metabolism

of a 'standard man', the weight of different organs, distribution data on internally administered chemical substances, and radioisotope data. Founded on these bases are extensive calculations and tables on maximum permissible body burden and concentration in water and in air for all important radioisotopes, together with statements about the critical organ in different cases. The conditions after a single ingestion are also discussed.

Sub-Committee III reports on protection against roentgen rays generated at potentials of 5 kV up to 2 MV and gives relatively detailed recommendations on the erection of plans for roentgen installations, survey and monitoring, and equipment and procedures for different kinds of roentgen work, including non-medical applications and unintentionally arising roentgen rays from electronic valves, television sets etc. An extensive Appendix gives diagrams, tables and formulae for calculating the protection barriers needed in different cases.

The united Sub-Committees IV and V present a short report on protection against roentgen rays above 2 MV, beta and gamma rays, and heavy particles, including neutrons and protons.

The volume is almost indispensable to anybody interested in radiation protection – and this is a large and rapidly increasing number of people.

Sven Benner.

RADIODIAGNOSTIC EN OPHTALMOLOGIE. Par E. Hartmann et E. Gilles. 411 pp., 497 illustrations. Masson et Cie, Paris 1955.

In this large work, one section of the wide field of roentgen diagnostics has been exhaustively treated by the cooperation of ophthalmologist and radiologist. The book is based upon an extensive material, which has enabled the more commonly occurring, as well as the more rare pathologic changes to be treated systematically.

The roentgenologic analysis of the orbit, especially as regards the topographic anatomy, is adequately presented. Thus, the orbital walls, canalis opticus, and fissura orbitalis superior and inferior, are all dealt with in separate chapters. In each such chapter, the various projections required are described, the value and importance of tomography discussed, and examples of pathologic changes given.

Exophthalmos is dealt with in a special chapter, in which the various forms of dislocation of the bulbus and the expansive processes which ordinarily cause them, are described. Tumours and cysts which may occur in the orbit are presented in tabular form together with their clinical signs and roentgen diagnostics.

In one long chapter, methods in use for demonstrating foreign bodies in the eye are selectively reviewed and in another chapter an account is given of roentgen examinations of the lachrymal ducts. Changes in the sella turcica in cases of tumours and aneurysms and their correlation to the occurrence of visual disturbances, are discussed in a special chapter.

Finally, in the last 85 pages of the book, a survey is made of pathologic changes occurring in the skull vault and short accounts of encephalography and cerebral arteriography are given. This section perhaps falls outside the sphere of ophthalmologic interest, being a neuroradiologic speciality.

The illustrative material of the book is comprehensive and informative. In many instances, it would have been easier to study the views if arrows had been inserted to indicate pathologic changes. There is, however, every reason for radiologists to welcome the appearance of this monograph on roentgen diagnostics in an important and difficult field.

Folke Knutsson.

BOOKS RECEIVED

We acknowledge with thanks under this heading books received for review, which we trust will be regarded as a sufficient mark of appreciation of the courtesy of the sender. The reviews of selected items will appear as soon as opportunity affords.

BIOCHEMICAL ASPECTS OF BASIC MECHANISMUS IN RADIOBIOLOGY. Editor: Harvey M. Pott. National Academy of Sciences. National Research Council, Washington 1955.

ANGIOGRAPHIC LOCALIZATION OF INTRACRANIAL MASSES. By Arthur Ecker and Paul A. Riemenschneider. Charles C. Thomas, Springfield, Ill. 1955.

AUTORADIOGRAPHY IN BIOLOGY AND MEDICINE. By George A. Boyd. Academic Press Inc., New York 1955.

ERLÄUTERUNGEN ZU DEN STRAHLENSCHUTZNORMEN FÜR MEDIZINISCHE RÖNTGENEINRICHTUNGEN, -ANLAGEN UND RÖNTGENSCHUTZKLEIDUNG, DIN 6811, 6812, 6813. Verfasst von H. Graf und A. Schaal. Georg Thieme Verlag, Stuttgart 1955.

RECENT ADVANCES IN RADIOLOGY. Third edition. By Thomas Lodge. J. & A. Churchill Ltd., London 1955.

DIE RÖNTGEN-UNTERSUCHUNG DES HERZENS UND DER GROSSEN GEFÄSSE. Von R. Janker, F. Grosse-Brockhoff, R. Haubrich, H. Lotzkes, A. Schaede & H. Hallerbach. W. Girardet Verlag, Wuppertal-Elberfeld 1955.

5° CONGRESO INTERAMERICANO DE RADIOLOGIA (THE INTER-AMERICAN COLLEGE OF RADIOLOGY). List of members. New York 1955.

ANNUAL REPORT ON THE RESULTS OF TREATMENT IN CARCINOMA OF THE UTERUS. Stockholm 1954.

RÖNTGEN-SCHICHTVERFAHREN. Grundlagen der technischen Entwicklung und der klinischen Anwendung für die Praxis. Von R. Griesbach & F. Kemper. Georg Thieme Verlag, Stuttgart 1955.

ATLAS OF ROENTGEN ANATOMY OF THE SKULL. By Lewis E. Etter. Charles C. Thomas, Springfield, Ill. 1955.

ÉPREUVES HÉMATO-BIOLOGIQUES DANS LE LYMPHOME MALIN. Par A.-P. Lachapèle & L.-J. André. Masson & Cie., Paris 1955.

PÄDIATRISCHER RÖNTGENATLAS. Von M. A. Lassrich, R. Prévot & K. H. Schäfer. Georg Thieme Verlag, Stuttgart 1955.

LA PNEUMOGINECOGRAFIA. F. Marchesi, L. Oliva, V. Albano & M. Maneschi. Edizioni Minerva Medica, Torino 1955.

LUNGENKREBS UND BRONCHOGRAPHIE. Von H. Anacker. Georg Thieme Verlag, Stuttgart 1955.

DIAGNOSIS OF CONGENITAL HEART DISEASE. By Sven R. Kjellberg, Edgar Mannheimer, Ulf Rudhe & Bengt Jonsson. The Year Book Publishers, Chicago 1955.

DIE KONGENITALEN MISSBILDUNGEN, IHREN URSACHEN UND PROPHYLAXE. Von Martin Wrete. Almqvist & Wiksell, Stockholm 1955.

NEUROLOGISCH-NEUROCHIRURGISCHE RÖNTGENDIAGNOSTIK UND ANDERE METHODEN ZUR ERKENNUNG INTRAKRANIALER ERKRANKUNGEN. Von R. Kautzky & K. J. Zülch. Springer-Verlag, Berlin 1955.